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ANNUAL PROGRESS REPORT, FISCAL YEAR 1977.(U)

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19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

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| Acute Mountain Sickness | Anaerobic Work Capacity | Cancer |
| Aerobic Fitness | Angiography | Carotid and Medullary Chemoreceptors |
| Altitude | Basal Metabolic Rate | |
| Alveolar-Arterial Oxygen Gradients | Biofeedback | Chronic Hypoxemia |
| Anaerobic Metabolism | Biophysics | Cold (Cont'd) |

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A report of progress on the research program of the US Army Research Institute of Environmental Medicine for Fiscal Year 1977 is presented as follows:

| Program No. | Project No. | Task No. | Title |
|---|---|---|---|
| 6.11.01.A | 3A161101A91C | 00 | In-House Laboratory Independent Research ; |
| 6.11.02.A | 3E161102BS08 | 05 | Defense Research Sciences, Army ; |
| 6.27.77.A | 3E762777AB45 | 00 | Environmental Stress; Physical Fitness, and Medical Factors in Military Performance . |


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Cold Induced Vasodilatation (CIVD)
Cold Injury
Cold Injury Prevention
Cold Pressor Test
Creatine Phosphokinase Lactate
Critical Thermal Maximum
Cryobiology
Cytochrome P-450
D-amphetamine
Dehydration
Disabilities
Dog Heatstroke Model
E. Coli Endotoxin Heatstroke
Energy Cost
Energy Expenditure
Environmental Medicine
Environmental Tolerance
Esophageal Temperature
Evaporative Cooling Index
Exercise Hyperthermia
Facial Rewarming
Fasciotomy
Fluid Compartments
Frostbite
Heat
Heat Production
Heatstroke Diagnosis
Heatstroke Model
Heatstroke Prevention
Heatstroke Prognosis
Hepatic Necrosis
High Altitude Pulmonary Edema
High Intensity Exercise
Human Performance at Altitude
Human Performance in Cold
Human Performance in Heat
Hyperthermia
Hypothermia
Hypovolemia
Hypoxia
Hypoxic Vasoconstriction
Infrared Thermography
Insulation (clo)
Isolated, Perfused Rat Liver
Job Fitness Requirements
Limulus Lysate
Metabolic Regulation
Microwave Radiometer
Military Occupational Specialties
Military Operations
Military Tactics
Moisture Permeability Index
Morphine
Muscle Contraction
Muscle Strength
Organ Wet/Dry Weight Ratios
Osteocytes
Perception of Effort
Performance Limits
Peripheral Blood Flow
Peritoneal Dialysis
Physical Fitness
Physical Fitness Standards
Physical Fitness Training
Prehydration
Psychological Inventories
Psychological Measures
Rat Heatstroke Model
Reactive Hyperemia
Squirrel Monkey
Submaximal Workload
Sustained Human Performance
Systemic Hypotension
Terrain Coefficients
Thermal Exchange
Thermoregulation
Thyroid Function
Tolerance Prediction
Treatment
US Military Academy
Vasoconstrictor Tone
Vasodilation
Ventilation-Perfusion Relationship
Ventilatory Muscle Training
Ventilatory Oscillations
Ventriculo-Cisternal Perfusion
Visual Search Performance
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US ARMY RESEARCH INSTITUTE OF ENVIRONMENTAL MEDICINE

NATICK, MASSACHUSETTS

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UNITED STATES ARMY
MEDICAL RESEARCH & DEVELOPMENT COMMAND

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APPENDICES

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| RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY | 1. AGENCY ACCESSION* | 2. DATE OF SUMMARY* | REPORT CONTROL SYMBOL |
|---|---|---|---|
| | DA OB 6135 | 77 10 01 | DD-DR&E(AR)636 |

| 3. DATE PREV SUM'RY | 4. KIND OF SUMMARY | 5. SUMMARY SCTY* | 6. WORK SECURITY* | 7. REGRADING* | 8a. DISB'N INSTR'N | 8b. SPECIFIC DATA-CONTRACTOR ACCESS | 9. LEVEL OF SUM |
|---|---|---|---|---|---|---|---|
| 76 08 20 | H. Terminated | U | U | NA | NL | [X] YES [ ] NO | A. WORK UNIT |

| 10. NO./CODES:* | PROGRAM ELEMENT | PROJECT NUMBER | TASK AREA NUMBER | WORK UNIT NUMBER |
|---|---|---|---|---|
| a. PRIMARY | 6.11.01.A | 3A161101A91C | 00 | 020 |
| b. CONTRIBUTING | | | | |
| c. CONTRIBUTING | | | | |

11. TITLE (Precede with Security Classification Code)*
(U) An Analgesic for Use in Cold Environments (22)

12. SCIENTIFIC AND TECHNOLOGICAL AREAS* 012900 Physiology; 016200 Stress Physiology; 0126 Pharmacology 003500 Clinical medicine; 005900 Environmental biology

| 13. START DATE | 14. ESTIMATED COMPLETION DATE | 15. FUNDING AGENCY | 16. PERFORMANCE METHOD |
|---|---|---|---|
| 76 04 | 77 09 | DA | C. In-House |

17. CONTRACT/GRANT
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b. NUMBER:* NOT APPLICABLE
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e. KIND OF AWARD: f. CUM. AMT.

| 18. RESOURCES ESTIMATE | | a. PROFESSIONAL MAN YRS | b. FUNDS (In thousands) |
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| | CURRENT | | |

19. RESPONSIBLE DOD ORGANIZATION
NAME:* USA RSCH INST OF ENV MED
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20. PERFORMING ORGANIZATION
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TELEPHONE: 955-2893
SOCIAL SECURITY ACCOUNT NUMBER:
ASSOCIATE INVESTIGATORS
NAME:
NAME: DA

21. GENERAL USE
Foreign Intelligence Not Considered

22. KEYWORDS (Precede EACH with Security Classification Code)
(U) Morphine; (U) Cold Injury; (U) d-amphetamine

23. TECHNICAL OBJECTIVE,* 24. APPROACH, 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)

23. (U) Morphine is the standard systemically-administered analgesic employed by the military in the treatment of battle casualties. One of the side effects of therapeutic doses of morphine is the lowering of body temperature. At low ambient temperatures, this effect of morphine deserves special consideration since it predisposes the casualty to the additional risk of cold injury. The administration of a combination of morphine and d-amphetamine has already been shown to be effective in eliminating the sedating and depressing effects of morphine while enhancing the level of analgesia. There is good reason to suppose that this drug combination will also negate the effect of morphine on body temperature, and thus reduce apprehension concerning its use in cold environments. To document the value of this drug combination, experiments on mice are needed to determine the effects of morphine plus amphetamine on rectal temperature, oxygen consumption, and activity.

24. (U)Groups of mice will be given the combination listed above and core temperature, oxygen consumption and level of activity will be recorded.

25. (U) 76 06 - 77 09 This work has been suspended due to the lack of a qualified investigator to evaluate, describe and conduct the necessary research.

*Available to contractors upon originator's approval.

| | |
|---|---|
| Program Element: | 6.11.01.A IN-HOUSE LABORATORY INDEPENDENT RESEARCH |
| Project: | 3A161101A91C In-House Laboratory Independent Research |
| Work Unit: | 020 An Analgesic for Use in Cold Environments |
| Study Title: | Rectal Temperatures of Mice as Affected by Morphine, d-Amphetamine and Their Combination |
| Investigator: | James J. Jaeger, CPT, MSC |

Background:

Morphine is a commonly used analgesic in the alleviation of pain on the battlefield. However, as a major side effect, cardiorespiratory depression is marked and temperature regulation is disturbed (1). These side effects are of particular concern when morphine is used in a cold environment where hypothermia is a major problem in the evacuation and treatment of wounded. The administration of morphine to a combat casualty in a cold environment may lead to pronounced cardiorespiratory depression and/or death. This project represents a long-term effort to determine if the administration of a combination of morphine and d-amphetamine will negate the hypothermic effect of morphine administration.

Progress:

To date the major effort in this project has been directed toward identification of an appropriate animal model for evaluation of the drug effects. Results have been negative, in that rodents (mice and rats) do not have temperature responses to morphine similar to those of humans. Evaluation of the literature, at present, offers no suitable model.

Literature search will continue; however, active research will be suspended until a qualified pharmacologist/physiologist is available to describe and conduct the necessary research.

Presentations:

None

Publications:

None

## LITERATURE CITED


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| 10. NO./CODES:* | PROGRAM ELEMENT | PROJECT NUMBER | TASK AREA NUMBER | WORK UNIT NUMBER |
|---|---|---|---|---|
| a. PRIMARY | 6.11.01.A | 3A161101A91C | 00 | 021 |
| b. CONTRIBUTING | | | | |
| c. CONTRIBUTING | | | | |

11. TITLE (Precede with Security Classification Code)*

(U) The Effects of Heat on the Structure and Function of Perfused Rat Liver (22)

12. SCIENTIFIC AND TECHNOLOGICAL AREAS*

005900 Environmental Biology; 002300 Biochemistry;012900 Physiology;010100Microbiology

| 13. START DATE | 14. ESTIMATED COMPLETION DATE | 15. FUNDING AGENCY | 16. PERFORMANCE METHOD |
|---|---|---|---|
| 76 04 | CONT | DA | C. In-House |

17. CONTRACT/GRANT

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b. NUMBER:*

c. TYPE: d. AMOUNT:

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| 18. RESOURCES ESTIMATE | | a. PROFESSIONAL MAN YRS | b. FUNDS (In thousands) |
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| FISCAL YEAR | PRECEDING 77 | 5.4 | 116.0 |
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19. RESPONSIBLE DOD ORGANIZATION

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ASSOCIATE INVESTIGATORS

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NAME: HAMLET, Murray P., D.V.M. DA

21. GENERAL USE

Foreign Intelligence Not Considered

22. KEYWORDS (Precede EACH with Security Classification Code) (U)Limulus Lysate;(U)E. coli Endotoxin Heatstroke; (U)Hepatic Necrosis;(U)Isolated, Perfused Rat Liver

23. TECHNICAL OBJECTIVE.* 24. APPROACH, 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)

23. (U)The objective of this research is to determine at what temperatures metabolic, histological, and ultrastructural changes occur in the isolated perfused rat liver due to heat exposure. These parameters will then be used to evaluate the role of the liver in heatstroke independent of the complex mechanisms operating in the whole animal. The effects of a variety of heat generated substances can also be ascertained. An understanding of the mechanisms of heat induced lesions may lead to the formulation of therapeutic agents specifically designed to negate these factors.

24. (U)Pathological changes in the liver are among the most consistent findings subsequent to heatstroke. A systematic study of heat-induced injury to the isolated perfused organ should yield valuable insight into the mechanisms of tissue damage independent of the complexities encountered with whole animals. By perfusing fluids at known temperatures, the critical temperatures for endothelial and parenchymal cell injury can be established using light and electron microscopy, potassium release, dye clearance, release of GPT, glucose metabolism and oxygen consumption. The effects of perfusate containing precise amounts of chemically pure substances thought to play a role in heatstroke or containing cellular fluids from heated animals can be ascertained.

25. (U)76 10 - 77 09 Bile production, potassium release, GPT, GOT, light and electron microscopy were used to compare isolated livers perfused at 37°C with livers perfused at 43°C. Severe hepatic injury was indicated by all parameters utilized in the 43°C group. The nature of the lesion suggests that factors induced by heat, in addition to heat alone, contribute to lesion in whole animals. These factors are under study. Quantitation of one of these factors, endotoxin, has been accomplished by the study of residual clottable protein in limulus amebocyte lysate after reaction with endotoxin.

*Available to contractors upon originator's approval.

Program Element: 6.11.01.A IN-HOUSE LABORATORY INDEPENDENT RESEARCH
Project: 3A161101A91C In-House Laboratory Independent Research
Work Unit: 021 The Effect of Heat on the Structure and Function of the Perfused Rat Liver
Study Title: Quantitation of Bacterial Endotoxin
Investigators: Wilbert D. Bowers, Jr., Ph.D., David Dubose, MS., Jerry M. Brown, Ph.D., and Murray P. Hamlet, D.V.M.

## Background:

Previous investigations have indicated an association of endotoxin with heatstroke in humans (1,3). Work in this institute has also shown this association in both dog and rat models for heatstroke. Information gathered from the dog heatstroke model indicates that the longer the survival past maximum body temperature, the greater the probability of the presence of circulating endotoxin. It appears that endotoxemia could play a significant role in the course of recovery if the subject is able to overcome the initial trauma of heat injury. Thus, the quantitation of circulating plasma endotoxin would be an important prognostic tool for the clinician. The in vivo techniques for indicating the presence and quantity of endotoxin are costly, time consuming, and difficult to perform (2). Presently, there is an in vitro technique which utilizes a basic defense system of the horseshoe crab (Limulus polyphemus) which protects it from gram negative infection. In short, the crab blood will form a gel around the site of infection, preventing its spread. It has been determined that this gelling is in response to the lipopolysaccaride (endotoxin) make-up of the cell wall of gram negative bacteria (5,6). Utilizing this phenomenon, lysates prepared from crab blood amebocytes have been used to test for the presence of endotoxin in a variety of test samples. Several quantitative procedures have been derived from this in vitro technique (4,7,8). All of these procedures are based on some comparison to a known purified endotoxin standard. An improvement in this techniques would be one in which endotoxin could be quantitated regardless of its type or state of purity. This would provide an accurate picture of endotoxin level in a sample. We have approached this problem

by examining Limulus lysate proteins after their reaction with endotoxin.

Progress:

It has been found that, if the reaction between endotoxin and Limulus lysate is stopped before it reaches a full gel, the level of endotoxin can be determined by the quantitation of certain Limulus proteins. This has been elucidated by the quantitation of endotoxin reacted Limulus proteins after polyactylamide gel electrophoresis. Through such an examination, proteins of approximate 68,000 molecular weight were found to decrease after reaction with endotoxin. The level of these proteins were found to be inversely proportional to the amount of endotoxin in the reaction. Using these observations, we have been successful in setting up standard curves for endotoxin. Sigma Chemical Company lysate and E coli endotoxin from the Associates of Cape Cod (ACC) were allowed to react for 15 minutes at 37°C at which time the reaction was stopped by vigorous agitation and lowering the temperature to 4°C. Reaction mixtures were then centrifuged under refrigeration at 25,000$^x$g. The resultant supernatant was applied to polyacrylamide gels and electrophoresed in tris buffer at 125V for 18 hours. Gels were fixed in sulfosalacylic acid and stained with solutions of 7% acetic acid. The Limulus proteins could then be quantitated by soft laser scanning densitometry. As can be seen in Table 1 as endotoxin level increased, Limulus protein level in the supernatant decreased.

Table 1. Limulus Protein Level in Supernate after 15 Minute Reaction with E. coli Endotoxin

| Endotoxin ng/ml | Protein Level* (A.U.) |
|---|---|
| 0.0 | 76.4 |
| 0.3 | 55.2 |
| 0.5 | 41.5 |
| 0.8 | 20.5 |
| 1.0 | 11.0 |

*A.U. = arbitrary units

Figure 1 shows a typical standard curve that can be established for endotoxin using this technique. Values for $R^2$ calculated by multiple linear regression showed that 97% of the variability in protein level was accounted for by endotoxin level.


Figure 1. Standard curve for E. coli endotoxin determined by quantitation of Limulus protein after reaction with endotoxin.

Since our goal was to develop a technique which could accurately quantitate endotoxin regardless of its type or state of purity, work continued to determine if there was a state in the reaction between endotoxin and Limulus proteins which was common to all endotoxins. To accomplish this, we utilized a very sensitive

lysate developed by ACC. This lysate was selected since the manner in which it reacted to endotoxin, at levels used to establish standard cures, appeared less affected by the type of endotoxin than other lysates. Table 2 shows a comparison of three lysate sources. As can be seen, the reaction by ACC lysate to three common endotoxin standards is the same. The other lysates showed a great deal of variability not only to different endotoxins but also to the same endotoxin of different states of purity.

Table 2. Comparison of the reactions of 3 types of Limulus lysate with 3 commonly used endotoxin standards

| Lysate | Reaction at 1 hour at 37°C — Endotoxins: E. coli (ACC) ng/ml | | | | E. coli (Difco) ng/ml | | | | S. flexneri (Sigma) ng/ml | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Type | 2.0 | 1.0 | 0.5 | 0.25 | 2.0 | 1.0 | 0.5 | 0.25 | 2.0 | 1.0 | 0.5 | 0.25 |
| Sigma | 4+ | 1+ | - | - | 4+ | 4+ | 1+ | - | 4+ | 3+ | - | - |
| ACC | 4+ | 4+ | 4+ | 4+ | 4+ | 4+ | 4+ | 4+ | 4+ | 4+ | 4+ | 4+ |
| Hemachemical | 4+ | 4+ | 4+ | 4+ | 4+ | - | - | - | 4+ | 4+ | - | - |

4+ = solid; 3+ = running gel; 2+ = clumbing; 1+ = increase in reaction viscosity; - = no reaction

Though the location of banded proteins on the polyacrylamide gels for ACC and Sigma lysates are the same, protein level in these bands appear to differ. The most significant difference lies in the low molecular weight region (68,000). Sigma lysate has more protein in this region than does ACC lysate. There is also a difference between the two lysates in the banding of proteins after reaction with endotoxin and polyacrylamide gel electrophoresis. Whereas Sigma lysate appears to lose protein only in the 68,000 molecular weight range, ACC lysate appears to lose protein only in the higher molecular weight areas as well. Figure 2 shows standard curves for S. flexneri using ACC lysate. One curve was determined by measurement of only 68,000 molecular weight range proteins and the other by

measurement of all proteins in the lysate after reaction. It can be seen that a greater slope for the standard curve was obtained when all proteins were measured. We have thus modified our procedure when using ACC lysate to include a measure of all proteins for standard curve determination.

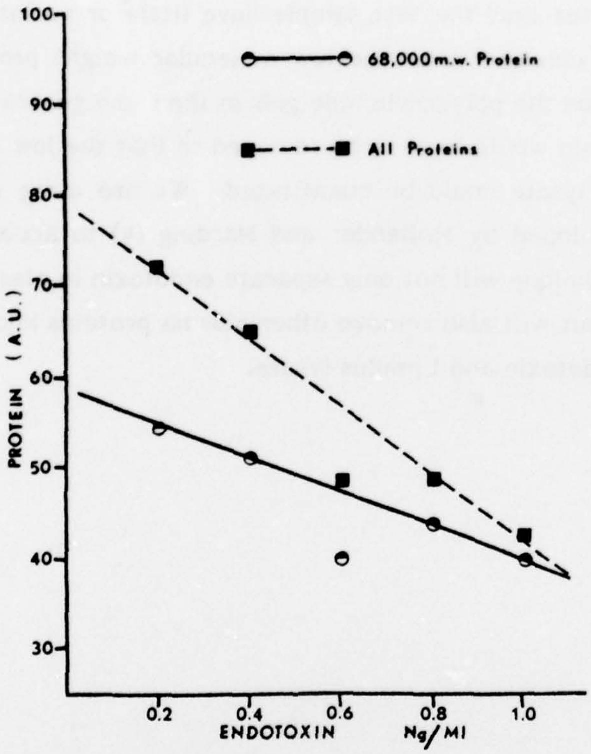


Figure 2. Comparison of standard curves for S. flexneri determined by quantitation of ACC Limulus proteins of the 68,000 molecular weight range and all proteins in the Limulus lysate.

Due to the extreme sensitivity of ACC lysate to endotoxin, it has been found more difficult to work with than Sigma lysate. Pipetting errors are accentuated and there appears to be a difficulty in stopping the reaction once it has been initiated. This has caused difficulty in reproducibility which was not noted when

using Sigma lysate. Though this is a problem, it is felt that ACC lysate offers the best opportunity for comparison of different endotoxins to determine if there is some point in the kinetics of the reaction between endotoxin and Limulus proteins which is similar for all endotoxins.

In addition, work is proceeding to adapt the above technique to measuring plasma endotoxin. Since this technique is based on the measurement of Limulus protein, it necessitates that the test sample have little or no interfering protein. This is especially a concern since the low molecular weight proteins (68,000) of Limulus lysate band on the polyacrylamide gels in the same general area as albumin (67,000). Thus albumin would have to be removed so that the low molecular weight proteins of Limulus lysate could be quantitated. We are using the gel filtration technique, first developed by Hollander and Harding (4) to accomplish this task. Fortunately, this technique will not only separate endotoxin in plasma from albumin and other proteins, but will also remove other plasma proteins known to inhibit the reaction between endotoxin and Limulus lysate.

Presentations:

None.

Publications:

None.

## LITERATURE CITED

1. Caridis, D. T., R. B. Reinhold, P. W. Woodruff, and J. Fine. Endotoxemia in man. Lancet. June, 24, 1381-1386, 1972.

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|---|---|
| Program Element: | 6.11.01.A IN-HOUSE LABORATORY INDEPENDENT RESEARCH |
| Project: | 3A161101A91C In-House Laboratory Independent Research |
| Work Unit: | 021 The Effects of Heat on the Structure and Function of the Perfused Rat Liver |
| Study Title: | The Effect of Heat on the Structure and Function of the Perfused Rat Liver |
| Investigators: | Wilbert D. Bowers, Jr., Ph.D.; Roger W. Hubbard, Ph.D., Murray P. Hamlet, D.V.M., John T. Maher, Ph.D., and Milton Mager, Ph.D. |

Background:

Pathological changes in the liver are among the most consistant findings in humans subsequent to heat overload. The evolution of liver damage in heatstroke occurring in cross country runners has been described by means of serial biopsies (1). At least mild pathological changes were observed in the livers of almost all of the 39 Bantu miners in another study (2). In each study, centrilobular necrosis was evident. Ultrastructural changes were observed even in patients who survived heatstroke (3).

The severity of heatstroke precludes human studies and thus, a rat model for heatstroke in humans has evolved (4). Utilizing this model system, centrilobular necrosis was also observed in rat liver subsequent to heatstroke (5).

In spite of the frequency of hepatic damage, its role in heatstroke remains obscure. The mechanisms responsible for severe injury or death are difficult to ascertain in the complexities and diverse sequelae of the intact animal or human.

A systematic study of heat-induced injury to the isolated perfused liver should yield valuable insight into the mechanisms of tissue damage. The critical temperatures for endothelial and parenchymal cell injury and subsequent events can be established using light and electron microscopy, bile production, potassium release, release of GPT and GOT, and oxygen consumption. Thus, the effects of the perfusate, heated to known temperatures, containing cellular fluids from heated animals, or containing precise amounts of chemically pure substances,

thought to play a role in heatstroke can be assertained.

Progress:

Since the purpose of this study was to establish a system in which individual parameters related to heatstroke could be evaluated, isolated rat livers were perfused with KRB without red blood cell in a non-recirculating system. It had been established that damage to the liver occurred between 42°C and 43°C (5,6). Therefore, our initial study compared control livers perfused at 37°C with livers perfused at 43°C, using 8 livers per group.

All of the conventional parameters (bile production, potassium release GPT, GOT) were monitored, and in addition, light and electron microscopic structures were examined.

Bile production by control livers was nearly linear over the 90 minute perfusion period, while production was severly restricted after 45 minutes at 43°C (Fig. 1).

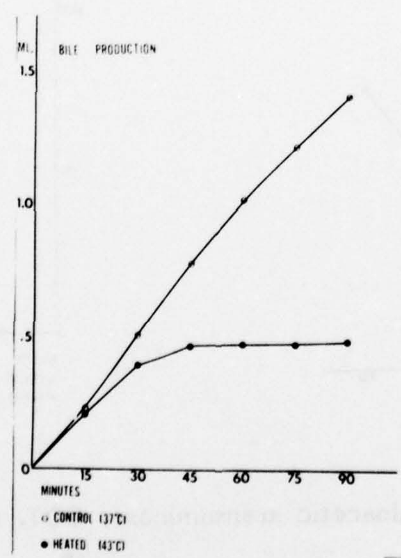


**Figure 1. Bile production by control and heated livers.**

Potassium released from heated livers exceeded that of control livers at every time interval (Table 1).

Table 1

POTASSIUM LEVELS IN EFFLUENT

| | Sample Time | | | | | | |
|---|---|---|---|---|---|---|---|
| | 0 | 15 | 30 | 45 | 60 | 75 | 90 |
| Control Mean | 5.74 | 5.86 | 5.85 | 5.91 | 5.94 | 5.99 | 5.98 |
| S.E.M. | .04 | .04 | .04 | .04 | .04 | .05 | .08 |
| Heated Mean | 5.70 | 5.90 | 5.93 | 7.06 | 6.17 | 6.09 | 6.14 |
| S.E.M. | .06 | .05 | .09 | .08 | .07 | .06 | .09 |

Both the GPT (Fig. 2) and GOT (Fig. 3), plotted as cumulative totals, indicated severe damage beyond 30 minutes exposure to 43$^{\circ}$C, and no evidence of damage in controls at 37$^{\circ}$C.

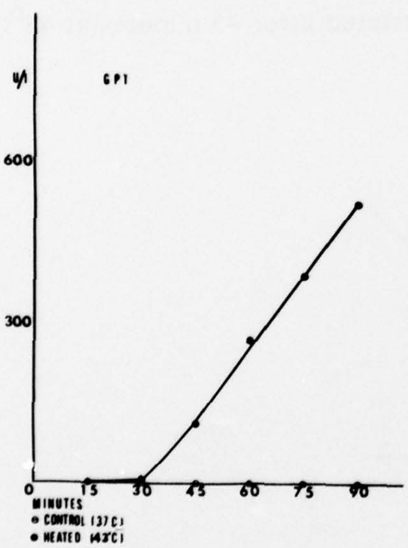


Figure 2

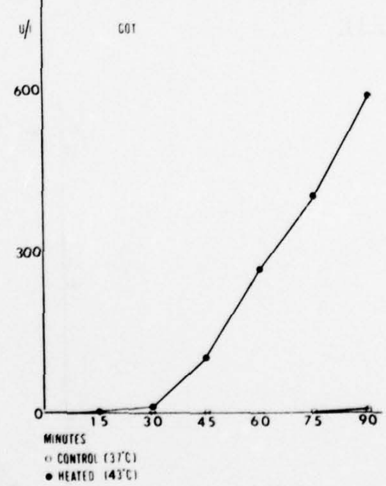


Figure 3

Figure 2. Glutamic-oxaloacetic transaminase, GOT, release from control and heated livers.

Figure 3. Glutamic-pyruvic transaminase, GPT, release from control and heated livers.

It thus appears that 30–45 minute exposure to 43°C is sufficient exposure to cause severe hepatic damage due to heat alone. However, the lesions observed by light and electron microscopy were not identical to those observed after whole animal heat exposure (4). This may indicate that other factors induced by heat exposure also contribute to the typical hepatic lesions. The effects of other factors and temperatures will be explored utilizing the same parameters for evaluation.

Presentations:

None.

Publications:

Bowers, W. D., R. W. Hubbard, I. Leav, R. Daum, M. Conlon, M. Hamlet, M. Mager, and P. Brandt. Histological and ultrastructural alterations of rat liver subsequent to heat overload. Arch. Path. in press.

## LITERATURE CITED

1. Bianchi, L., H. Ohnacker, K. Beck and M. Zimmerli-Ning. Liver damage in heatstroke and its regression. A biopsy study. Human Path. 3:237-249, 1972.

2. Kew, M., I. Bersohn, H. Seftel and G. Kent. Liver damage in heatstroke. Am. J. Med. 49:192-202, 1970.

3. Minick, O. and M. Kew. Ultrastructural changes in patients with heatstroke. Proc. Electron Microscopy Society of America. 28th Annual Meeting. Houston: 1970, P210.

4. Hubbard, R., W. Matthew, J. Linduska, F. Curtis, W. Bowers, I. Leav and M. Mager. The laboratory rat as a model for hyperthermic syndromes in humans. Am. J. Physiol. 231:1119-1123, 1976.

5. Bowers, W. D., R. W. Hubbard, I. Leav, R. Daum, M. Conlon, M. Hamlet, M. Mager, and P. Brandt. Histological and ultrastructural alterations of rat liver subsequent to heat overload. Arch. Path. in press.

6. Collins, F. G., and J. L. Skibba. Effect of hyperthermia (37-45°C) on gluconeogenesis, urea synthesis of oxygen consumption in the perfused rat liver. Fed. Proc. 36:302, 1977.

(81022)

**RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY**

| 1. AGENCY ACCESSION* | 2. DATE OF SUMMARY* | REPORT CONTROL SYMBOL |
|---|---|---|
| DA 0B 6132 | 77 10 01 | DD-DR&E(AR)636 |

| 3. DATE PREV SUM'RY | 4. KIND OF SUMMARY | 5. SUMMARY SCTY* | 6. WORK SECURITY* | 7. REGRADING* | 8a. DISB'N INSTR'N | 8b. SPECIFIC DATA-CONTRACTOR ACCESS | 9. LEVEL OF SUM |
|---|---|---|---|---|---|---|---|
| 76 08 20 | D. Change | U | U | N/A | N/L | [X] YES [ ] NO | A. WORK UNIT |

| 10. NO./CODES:* | PROGRAM ELEMENT | PROJECT NUMBER | TASK AREA NUMBER | WORK UNIT NUMBER |
|---|---|---|---|---|
| a. PRIMARY | 6.11.01.A | 3A161101A91C | 00 | 022 |
| b. CONTRIBUTING | | | | |
| c. CONTRIBUTING | | | | |

11. TITLE (Precede with Security Classification Code)*
(U) Ventilatory Control Mechanisms at High Altitude (22)

12. SCIENTIFIC AND TECHNOLOGICAL AREAS*
012900 Physiology; 005900 Environmental Medicine; 016200 Stress Physiology

| 13. START DATE | 14. ESTIMATED COMPLETION DATE | 15. FUNDING AGENCY | 16. PERFORMANCE METHOD |
|---|---|---|---|
| 75 01 | CONT | DA | In-House |

17. CONTRACT/GRANT
a. DATES/EFFECTIVE: EXPIRATION:
b. NUMBER:* NOT APPLICABLE
c. TYPE: d. AMOUNT:
e. KIND OF AWARD: f. CUM. AMT.

| 18. RESOURCES ESTIMATE | | a. PROFESSIONAL MAN YRS | b. FUNDS (In thousands) |
|---|---|---|---|
| FISCAL YEAR | PRECEDING 77 | 3.6 | 50 |
| | CURRENT 78 | 3 | 87.9 |

19. RESPONSIBLE DOD ORGANIZATION
NAME:* USA RSCH INST OF ENV MED
ADDRESS:* Natick, MA 01760
RESPONSIBLE INDIVIDUAL
NAME: DANGERFIELD, HARRY G., M.D., COL, MC
TELEPHONE: 955-2811

20. PERFORMING ORGANIZATION
NAME:* USA RSCH INST OF ENV MED
ADDRESS:* Natick, MA 01760
PRINCIPAL INVESTIGATOR (Furnish SSAN if U.S. Academic Institution)
NAME:* MAHER, John T., Ph.D.
TELEPHONE: 955-2851
SOCIAL SECURITY ACCOUNT NUMBER:
ASSOCIATE INVESTIGATORS
NAME: GABEL, Ronald, A., M.D.
NAME: 955-2828 DA

21. GENERAL USE
Foreign Intelligence Not Considered

22. KEYWORDS (Precede EACH with Security Classification Code) (U)Chronic Hypoxemia; (U)Carotid and Medullary Chemoreceptors; (U)Ventriculo-Cisternal Perfusion; (U)Ventilatory Oscillations

23. TECHNICAL OBJECTIVE.* 24. APPROACH, 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)

23. (U) The physiologic processes which control ventilation of man at high altitude are not fully understood. The objective of this work unit is to gain new knowledge of ventilatory control, with emphasis on adaptations within the control system during exposure to chronic hypoxemia, as experienced during sojourn at high terrestrial altitudes. A thorough understanding of this aspect of altitude physiology is essential in defining new approaches for enhancing adaptation of the soldier to high terrestrial elevations.

24. (U) An integrated program is under way to analyze contributions of both the carotid body and medullary chemoreceptors to the ventilatory adaptations of man to hypocapnic hypoxia, including interactions between the two chemoreceptors. Additional studies to determine the relationship between the ventilatory controller and effector, as exemplified by influences of increased inspiratory flow resistance on the ventilatory response of man to hypoxia or hypercapnia, are included.

25. (U) 76 10 - 77 09 In twelve normal soldiers exposed to an altitude of 4,300 meters, an oscillation of pulmonary ventilation was found, indicating instability of the regulation of breathing under these conditions. (2) Methods have been developed for indirect measurement of the ionic composition of cerebral interstitial fluid in unanesthetized goats. Based upon the study of nine goats at sea level and eight goats after five days at high altitude, it appears that the cerebral interstitial fluid is more acid at high altitude than at sea level.

*Available to contractors upon originator's approval

DD FORM 1 MAR 68 1498 PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE. DD FORMS 1498A, 1 NOV 65 AND 1498-1, 1 MAR 68 (FOR ARMY USE) ARE OBSOLETE.

| | |
|---|---|
| Program Element: | 6.11.01.A IN-HOUSE LABORATORY INDEPENDENT RESEARCH |
| Project: | 3A161101A91C In-House Laboratory Independent Research |
| Work Unit: | 022 Ventilatory Control Mechanisms at High Altitude |
| Study Title: | Altitude-Induced Breathing Patterns in Man |
| Investigators: | Ronald A. Gabel, M.D., Vladimir Fencl, M.D., Paul J. Brusil, Ph.D., Richard E. Kronauer, Ph.D., Thomas Waggener, Ronald E. Jackson, MAJ, MC, M.P.H. |

Background:

At high terrestrial elevations (3500-4500 meters), limitations in adaptation of the respiratory system may hamper the mental and physical performance of the soldier (1). The primary environmental stress at high altitude is a lower content of oxygen in the inspiratory air than at sea level. Thus, performance suffers from inability of the human body to compensate fully for environmentally-induced hypoxia. However, several physiologic defenses against hypoxia exist, two of them involving the ventilatory control system. Hyperventilation occurs almost immediately upon exposure to hypoxia, owing to stimulation of the carotid-body chemoreceptors by a reduction in oxygen tension of the arterial blood. After this initial response to hypoxia, resting ventilation is elevated an additional increment over the next five days or so through a process thought to involve a reduction in pH at medullary chemoreceptors in the brainstem (2).

Recent studies have shown that, besides these quantitative increases in pulmonary ventilation at high altitude, there may also be qualitative alterations in breathing patterns during exposure to prolonged hypoxia (3). Normally, during quiet breathing at rest, tidal volume ($V_T$) and respiratory frequency (f) vary reciprocally, such that an increase in one is accompanied by a decrease in the other. Therefore, there is usually less breath-to-breath variation in their product, ventilation ($\dot{V}_E$), than in either component. Recent studies, however, have shown that the reciprocal relationship between $V_T$ and f is impaired in some subjects at high altitude. This loss of normal ventilatory regulation manifests itself as an oscillation in $\dot{V}_E$ caused by periodic changes in $V_T$ and f which are not compensated for by mutually

reciprocal changes in these two variables. In fact, the two variables sometimes phasically increase and decrease together, which produces maximum instability of $\dot{V}_E$.

Progress:

Resting ventilation of 12 normal young volunteer subjects was measured at sea level and at altitudes of 2440-4300 meters simulated in a high altitude chamber, using magnetometers placed on chest and abdomen (4). The subjects were unaware that their ventilation was being measured, in that they were told only that the magnetometers were being used to measure changes in their thoracic and abdominal dimensions. No mouthpiece or face mask was required.

To evaluate oscillatory breathing patterns quantitatively, we define strength of ventilatory oscillations (M) in which there were no periods of apnea as $M = (\dot{V}_{max} - \dot{V}_{min}) / (\dot{V}_{max} + \dot{V}_{min})$, where $\dot{V}_{max}$ and $\dot{V}_{min}$ are maximum and minimum ventilation of individual breaths in an oscillatory cycle. The ventilation produced by a single breath was calculated by dividing tidal volume by the time elapsed between beginning of inspiration and end of expiration.

When apnea occurs in an oscillatory cycle, we redefine strength of ventilatory oscillations as $M = T_c/(T_c-T_a)$, where $T_c$ is period of the oscillatory cycle and $T_a$ is duration of apnea. We refer to such oscillatory cycles as apneic oscillations. M is greater than 1 during apneic oscillations, and M is less than 1 when apnea does not occur.

All 12 subjects showed apneic oscillations at 4300 meters, and no apnea was seen at sea level. Apneic oscillations were seen more frequently above 2740 meters. Period of the apneic oscillatory cycle lengthened about 2 seconds for each 1 unit increase in M; the period also shortened with increases in altitude. Range for the cycle period was 12-34 seconds.

In Table 1 are summarized the results of all test sessions at 4300 meters for five of the subjects whose data have been analyzed in detail. Included is the percentage of time at 4300 meters during which ventilation oscillated to the point of apnea, along with the average cycle period. Cycle period tended to be constant for a given subject during different test sessions at a given altitude, even on different days.

TABLE 1 Relative Duration and Cycle Period of Apneic Oscillations at 4300 Meters

| Subject Number | Test Day | Test Session | % of Time M > 1 | Cycle Period (Sec) |
|---|---|---|---|---|
| 1 | 2 | 3 | 51 | 17.3 |
| 2 | 1 | 2 | 48 | 19.1 |
| 2 | 1 | 3 | 55 | 18.9 |
| 2 | 2 | 3 | 56 | 19.6 |
| 3 | 1 | 2 | 77 | 12.9 |
| 3 | 2 | 3 | 54 | 13.5 |
| 5 | 1 | 1 | 37 | 18.3 |
| 5 | 1 | 2 | 14 | 17.0 |
| 5 | 2 | 3 | 13 | 16.8 |
| 12 | 1 | 1 | 43 | 16.4 |
| 12 | 1 | 2 | 83 | 16.5 |
| 12 | 1 | 3 | 21 | 16.6 |
| 12 | 2 | 2 | 3 | 16.5 |

In three subjects studied during ascent from sea level to 3350 or 4300 meters, apneic oscillations were seen within about four minutes after arrival at high altitude. Preliminary analysis of the data suggests that, at a given altitude, the minute ventilation when $M > 1$ (apneic oscillations) is about 20 percent greater than the average minute ventilation when $M < 0.5$ (weak or absent oscillations).

**Presentations:**

Waggener, T., P. Brusil, R. Kronauer, and R. Gabel. Strength and period of ventilatory oscillations in unacclimatized humans at high altitude. Presented, Annual Meeting, American Physiological Society, Hollywood, FL, 9-14 October 1977. The Physiologist, 20:98, 1977.

**Publications:**

None

LITERATURE CITED

1. Hegnauer, A. H. Editor: Biomedical Problems of High Terrestrial Elevations. Proceedings of a symposium held at US Army Research Institute of Environmental Medicine, Natick, MA, 16-17 October 1967.

2. Kellogg, R. H. Oxygen and carbon dioxide in the regulation of respiration. Fed. Proc. 36:1658-1663, 1977.

3. Kronauer, R., P. Brusil, P. Gulesian, Jr., T. Waggener. An altitude induced respiratory oscillator - occurrences and general description. The Physiologist 19:259, 1976.

4. Mead, J., N. Peterson, G. Grimby. Pulmonary ventilation measured from body surface movements. Science 156:1383-1384, 1967.

| | |
|---|---|
| Program Element: | 6.11.01.A IN-HOUSE LABORATORY INDEPENDENT RESEARCH |
| Project: | 3A161101A91C In-House Laboratory Independent Research |
| Work Unit: | 022 Ventilatory Control Mechanisms at High Altitude |
| Study Title: | Cerebral Fluids in Prolonged Respiratory Acid-Base Imbalance |
| Investigators: | Vladimir Fencl, M.D., Ronald A. Gabel, M.D., Danney L. Wolfe, CPT, VC |

Background:

Dempsey and colleagues have presented convincing evidence that the lumbar cerebrospinal fluid (CSF) of humans during acclimatization to high altitude becomes alkaline relative to normal sea-level values (1,2,3). We have confirmed this and have extended the findings by obtaining data in humans which permitted us to estimate pH in the large-cavity intracranial CSF (as opposed to lumbar CSF); here, too, pH of the CSF increased during five days of acclimatization to a simulated altitude of 4267 meters (4). In the past, it was widely accepted that the gradual increase in pulmonary ventilation at high altitude results from a reduction in pH of the CSF owing to a fall in bicarbonate concentration ($[HCO_3^-]$) (5). This explanation for ventilatory acclimatization no longer appears plausible because of Dempsey's and our data showing that the CSF becomes alkaline while pulmonary ventilation increases during the first five days or so at high altitude.

The cerebral interstitial fluid (ISF) would be an alternative site at which acid-base changes might occur to produce an increase in ventilation during prolonged hypoxia or hypocapnia or both. In normal acid-base balance, as well as during stable metabolic acidosis and alkalosis, the ionic composition of the cerebral ISF is the same as in the CSF (6). The pH of cerebral fluids during prolonged respiratory alkalosis induced by chronic hypoxia is unknown, however. It is possible that, in humans acclimated to high altitude, pH of the ISF in contact with incracranial chemoreceptors is lower than that of CSF.

## Progress:

We studied the ionic composition of cerebral ISF in goats at sea level and after adaptation to high altitude. Nine goats were successfully operated on and provided with carotid loops for repeated sampling of arterial blood and with chronic implants of nylon guide tubes for repeated punctures of the lateral ventricles and of cisterna magna, for aseptic ventriculo-cisternal perfusions with sterile artificial CSF of variable ionic composition. The techniques of Pappenheimer et al. (7) and Fencl et al. (6) were applied. Sterile mock CSF of the following composition was prepared: $Na^+$ 155, $K^+$ 3.0, $Ca^{++}$ 2.6, $Mg^{++}$ 1.6, $Cl^-$ 138, $HCO_3^-$ 22 (milliequivalents/liter), inorganic P 0.5 (mM/L). Variations in [$HCO_3^-$] (15 mM/L and 28 mM/L) were balanced by equivalent changes of $Cl^-$. $^3H$ - Inulin (approximately 3 nanocurie/ml) was added to the perfusate for measurement of rate of bulk absorption and formation of CSF (8) and for calculation of net transependymal exchange of ions between the perfusate and the brain tissue.

Nine perfusions with artificial CSF of three different [$HCO_3^-$] were performed at sea level, and eight perfusions after five days at a simulated altitude of 4300 meters (barometric pressure 470 torr) in a hypobaric chamber. Exchanges of $HCO_3^-$, $Cl^-$, and lactate between the perfusate and the brain tissue were measured. These data are now being analyzed to determine the conditions of "zero transependymal flux" which define the steady-state composition of the cerebral ISF in the condition under study. It is anticipated that the results will shed light on the role of the ionic composition of cerebral ISF in the ventilatory adaptation to high altitude.

## Presentations:

None

## Publications:

None

## LITERATURE CITED


1. Dempsey, J. A., H. V. Forster, and G. A. DoPico. Ventilatory acclimatization to moderate hypoxemia in man. J. Clin. Invest. 53:1091-1100, 1974.

2. Dempsey, J. A., H. V. Forster, N. Gledhill, and G. A. DoPico. Effects of moderate hypoxemia and hypocapnia on CSF [$H^+$] and ventilation in man. J. Appl. Physiol. 38:665-674, 1975.

3. Forster, H. V., J. A. Dempsey, and L. W. Chosey. Incomplete compensation of CSF [$H^+$] in man during acclimatization to high altitude (4300 m). J. Appl. Physiol. 38:1067-1072, 1975.

4. Weiskopf, R. B., R. A. Gabel, and V. Fencl. Alkaline shift in lumbar and intracranial CSF in man after 5 days at high altitude. J. Appl. Physiol. 41:93-97, 1976.

5. Severinghaus, J. W., R. A. Mitchell, B. W. Richardson, and M. M. Singer. Respiratory control at high altitude suggesting active transport of CSF pH. J. Appl. Physiol. 18:1155-1166, 1963.

6. Fencl, V., T. B. Miller, and J. R. Pappenheimer. Studies on the respiratory response to disturbances of acid-base balance, with deductions concerning the ionic composition of cerebral interstitial fluid. Am. J. Physiol. 210:459-472, 1966.

7. Pappenheimer, J. R., S. R. Heisey, E. F. Jordan, and J. deC. Downer. Perfusion of the cerebral ventricular system in unanesthetized goats. Am. J. Physiol. 203:763-774, 1962.

8. Heisey, S. R., R. D. Held, and J. R. Pappenheimer. Bulk flow and diffusion in the cerebrospinal fluid system of the goat. Am. J. Physiol. 203:775-781, 1962.

(81023)

| RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY | 1. AGENCY ACCESSION* | 2. DATE OF SUMMARY* | REPORT CONTROL SYMBOL |
|---|---|---|---|
| | DA OB 6138 | 77 10 01 | DD-DR&E(AR)636 |

| 3. DATE PREV SUM'RY | 4. KIND OF SUMMARY | 5. SUMMARY SCTY* | 6. WORK SECURITY* | 7. REGRADING* | 8a. DISB'N INSTR'N | 8b. SPECIFIC DATA-CONTRACTOR ACCESS | 9. LEVEL OF SUM |
|---|---|---|---|---|---|---|---|
| 77 09 02 | H.Terminated | U | U | NA | NL | [X] YES [ ] NO | A. WORK UNIT |

| 10. NO./CODES:* | PROGRAM ELEMENT | PROJECT NUMBER | TASK AREA NUMBER | WORK UNIT NUMBER |
|---|---|---|---|---|
| a. PRIMARY | 6.11.01.A | 3A161101A91C | 00 | 023 |
| b. CONTRIBUTING | | | | |
| c. CONTRIBUTING | | | | |

11. TITLE (Precede with Security Classification Code)*
(U) Isolated Cat Paw Model for Cold Induced Vasodilation (22)

12. SCIENTIFIC AND TECHNOLOGICAL AREAS*
002600 Biology; 005900 Environmental Biology; 012900 Physiology

| 13. START DATE | 14. ESTIMATED COMPLETION DATE | 15. FUNDING AGENCY | 16. PERFORMANCE METHOD |
|---|---|---|---|
| 10 76 | 77 09 | DA | C. In-House |

17. CONTRACT/GRANT
a. DATES/EFFECTIVE: EXPIRATION:
b. NUMBER:* NOT APPLICABLE
c. TYPE: d. AMOUNT:
e. KIND OF AWARD: f. CUM. AMT.

| 18. RESOURCES ESTIMATE | | a. PROFESSIONAL MAN YRS | b. FUNDS (In thousands) |
|---|---|---|---|
| FISCAL YEAR | PRECEDING 77 | .7 | 15.7 |
| | CURRENT | | |

19. RESPONSIBLE DOD ORGANIZATION
NAME:* USA RSCH INST OF ENV MED
ADDRESS:* Natick, MA 01760
RESPONSIBLE INDIVIDUAL
NAME: DANGERFIELD, HARRY G., M.D., COL, MC
TELEPHONE: 955-2811

20. PERFORMING ORGANIZATION
NAME:* USA RSCH INST OF ENV MED
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TELEPHONE: 955-2866
SOCIAL SECURITY ACCOUNT NUMBER:
ASSOCIATE INVESTIGATORS
NAME: BERBERICH, Joel J., CPT, MSC
NAME: 955-2863 DA

21. GENERAL USE
Foreign Intelligence Not Considered

22. KEYWORDS (Precede EACH with Security Classification Code)
(U) Cold Injury; (U) CIVD; (U) Vasodilation; (U) Vasoconstrictor Tone

23. TECHNICAL OBJECTIVE,* 24. APPROACH, 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)

23. (U)Presumably cold-induced vasodilation (CIVD) seen in man is a special case of proportional blood flow control to the cold extremity seen in animals. CIVD can, however, be reproduced in the extremities of two animals: the monkey and the cat. It is CIVD which keeps the extremities warm in the cold and prevents frostbite, but why CIVD cannot be prolonged in man is a paradox. This study proposes to investigate the possibility of using the isolated cat paw as an animal model for studying CIVD by comparison of responses to the intact animal with and without sympathectomy. One specific hypothesis that would be evaluated is the relative importance of active vasodilator substances in CIVD. Animals would be treated with an alpha-blocking agent in order to decrease vasoconstrictor tone. With cold exposure, one might then predict enhanced vasodilation cycles (enhanced CIVD) if an active vasodilator substance were a major factor in contrast to a continuous vasodilation at a higher temperature if this were the case.

24. (U)Intact and sympathectomized animals will have one paw subjected to a standard cooling procedure to define the DIVD response. Chemical substances that are known to alter blood vessel function in extremities will be utilized to evaluate their effects on CIVD.

25. (U)76 10 - 77 09 Terminated

*Available to contractors upon originator's approval.

DD FORM 1 MAR 68 1498 PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE. DD FORMS 1498A, 1 NOV 65 AND 1498-1, 1 MAR 68 (FOR ARMY USE) ARE OBSOLETE.





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| RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY | 1. AGENCY ACCESSION* | 2. DATE OF SUMMARY* | REPORT CONTROL SYMBOL |
|---|---|---|---|
| | DA OB 6131 | 77 10 01 | DD-DR&E(AR)636 |

| 3. DATE PREV SUM'RY | 4. KIND OF SUMMARY | 5. SUMMARY SCTY* | 6. WORK SECURITY* | 7. REGRADING* | 8a. DISB'N INSTR'N | 8b. SPECIFIC DATA-CONTRACTOR ACCESS | 9. LEVEL OF SUM |
|---|---|---|---|---|---|---|---|
| 77 09 02 | C. Completed | U | U | NA | NL | ☒ YES ☐ NO | A. WORK UNIT |

| 10. NO./CODES:* | PROGRAM ELEMENT | PROJECT NUMBER | TASK AREA NUMBER | WORK UNIT NUMBER |
|---|---|---|---|---|
| a. PRIMARY | 6.11.01.A | 3A161101A91C | 00 | 024 |
| b. CONTRIBUTING | | | | |
| c. CONTRIBUTING | | | | |

11. TITLE (Precede with Security Classification Code)*

(U)Pulmonary Gas Exchange During Exercise at Sea Level and Altitude (22)

12. SCIENTIFIC AND TECHNOLOGICAL AREAS*

012900 Physiology; 05900 Environmental Biology; 016200 Stress Physiology

| 13. START DATE | 14. ESTIMATED COMPLETION DATE | 15. FUNDING AGENCY | 16. PERFORMANCE METHOD |
|---|---|---|---|
| 75 01 | 77 09 | DA | In-House |

17. CONTRACT/GRANT

a. DATES/EFFECTIVE: EXPIRATION:

b. NUMBER:* NOT APPLICABLE

c. TYPE: d. AMOUNT:

e. KIND OF AWARD: f. CUM. AMT.

| 18. RESOURCES ESTIMATE | | a. PROFESSIONAL MAN YRS | b. FUNDS (In thousands) |
|---|---|---|---|
| FISCAL YEAR | PRECEDING 77 | 1.6 | 33 |
| | CURRENT | | |

19. RESPONSIBLE DOD ORGANIZATION

NAME:* USA RSCH INST OF ENV MED

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RESPONSIBLE INDIVIDUAL

NAME: DANGERFIELD, HARRY G., M.D., COL, MC

TELEPHONE: 955-2811

20. PERFORMING ORGANIZATION

NAME:* USA RSCH INST OF ENV MED

ADDRESS:* Natick, MA 01760

PRINCIPAL INVESTIGATOR (Furnish SSAN if U.S. Academic Institution)

NAME:* MAHER, John T., Ph.D.

TELEPHONE: 955-2851

SOCIAL SECURITY ACCOUNT NUMBER:

21. GENERAL USE

Foreign Intelligence Not Considered

ASSOCIATE INVESTIGATORS

NAME: SYLVESTER, Jimmie T., M.D., MAJ, MC

NAME: 955-2894 DA

22. KEYWORDS (Precede EACH with Security Classification Code) (U)Hypoxic Vasoconstriction; (U)Ventilation-Perfusion Relationship; (U)Alveolar-Arterial Oxygen Gradients; (U)Cytochrome P-450

23. TECHNICAL OBJECTIVE,* 24. APPROACH, 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)

23. (U) To determine how exercise and exposure to high altitude affect the transfer of oxygen in the lung and to determine the mechanism by which low oxygen pressures in the alveolar gas affects the pulmonary circulation.

24. (U) In the normal lung, oxygen transfer depends mainly upon the relationship between flow of air and blood through the lung. We have developed techniques which allow assessment of this relationship and have applied them in an animal model to determine the efficiency of the lung in oxygen transfer. In addition, we have investigated the mechanism by which the pulmonary circulation responds to low pressures of oxygen in the alveolar gas.

25. (U) 76 10 - 77 09 In order to assess gas exchange during altitude exposure at rest and during exercise, we developed an awake dog preparation which allowed measurement of numerous physiologic parameters. Chromatographic analysis of arterial and mixed venous blood and mixed expired air were perfected and used in this preparation. Results of these studies indicate that although gas exchange deteriorates somewhat during exposure to exercise at high altitude, the total ventilation of the lungs more than compensates for this deterioration so as to prevent an impairment of oxygen transfer in the lung. We also found that for a given level of exercise, oxygen consumption was lower at altitude than at sea level. This implies that the body has the ability to control its metabolism in response to a decrease in the supply of oxygen. The mechanism of this control is unclear. In addition, we have determined with an isolated pig lung preparation that the pulmonary vasoconstrictor response to alveolar hypoxia may depend upon the presence of desaturated cytochrome P-450. Cytochrome P-450 is a hemoprotein found in most organs of the body. This work unit has been completed.

*Available to contractors upon originator's approval

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* U.S. GPO: 1974-540-843/8691

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| | |
|---|---|
| Program Element: | 6.11.01.A IN-HOUSE LABORATORY INDEPENDENT RESEARCH |
| Project: | 3A161101A91C In-House Laboratory Independent Research |
| Work Unit: | 024 Pulmonary Gas Exchange during Exercise at Sea Level and Altitude |
| Study Title: | Pulmonary Gas Exchange during Exercise at Sea Level and Altitude |
| Investigators: | Jimmie T. Sylvester, MAJ, MC, Allen Cymerman, Ph.D., Donald H. Horstman, Ph.D. and Danney L. Wolfe, CPT, VC |

Background:

Normally there is a difference between the alveolar and the arterial partial pressures of oxygen. This difference in a normal subject averages 5 to 10 mm Hg and results from the inefficiency of the lung as a gas exchanger. During exercise at high altitude, this gradient increases (1), indicating that the efficiency of oxygen exchange in the lung has decreased. This must result from either a change in the relationship between ventilation and perfusion in the lung or from a change in the lung's ability to diffuse oxygen. Thus, the first goal of the study was to determine if the relationship between ventilation and perfusion in the lung could account for the diminished efficiency of oxygen exchange during exercise at a high altitude.

There are many reasons to suspect that altitude exposure might change the relationship between ventilation and perfusion in the lung. One is the fact that the pulmonary arterial pressure increases remarkably when alveolar oxygen pressure decreases. This has been known since Von Euler and Liljestrand (4) performed their classical experiments in the cat. An increase in arterial pressure would be expected to improve perfusion in the lung, especially in the apices. The mechanisms by which hypoxia causes an increase in pulmonary arterial pressure are unknown. The current possibilities were recently reviewed by Fishman (5), who narrowed the field to two: an indirect effect of hypoxia produced by local release of vasoactive agents and a direct effect on pulmonary vascular smooth muscle. We became interested in the possibility that a hemoprotein might mediate the pulmonary vascular response to hypoxia, i.e., whether cytochrome P-450 might act in this manner. Thus, the second part of the study was designed to determine if this was a reasonable possibility.

Progress:

The first two years of this project were concerned with the development of measurement techniques and animal preparations. The chromatographic analysis of inert gases from samples of blood and expired air was developed and perfected. An awake dog preparation was also developed. In this preparation blood samples could be withdrawn for analysis from a carotid arterial loop. Mixed venous samples were obtained from a pulmonary artery catheter. Ventilatory parameters were measured from a chronic tracheostomy. After training the animals to exercise on a treadmill, they were studied at rest and during exercise, at sea level and at high altitude. The results from these experiments are still being analyzed, but preliminary analysis reveals that the relationship between ventilation and perfusion in the lung deteriorates somewhat during exercise at high altitude. This did not lead to a worsening of the gradient between the alveolar and arterial oxygen tensions, however, because of a remarkable increase in total ventilation which was sufficient to decrease the gradient slightly. Another interesting finding from this study was that for a given level of exercise, oxygen consumption was lower at high altitude than it was at sea level.

A second animal preparation was developed for the study of the pulmonary circulation. This was a pig lung perfused in situ in such a way that pulmonary artery pressure and flow, and ventilation could be precisely controlled. In these animals we administered agents which bind to the heme ion of cytochrome P-450 and found that these agents prevented the vasoconstrictor response to hypoxia. The effects of one of these agents (metyrapone) on the relationship between pulmonary arterial pressure and flow is shown in Figure 1. This relationship is an index of the flow resistive properties of the lung. A shift of the pressure-flow relationship to the right or a decrease in its slope indicates the occurrence of vasoconstriction. It is obvious from the upper left panel of this figure that switching the animal from a normoxic to hypoxic gas mixture caused pulmonary vasoconstriction. It is equally obvious that when the same exposures were performed in the animal after the administration of metyrapone, the response to hypoxia was markedly diminished. As seen in the lower left panel, $F2_{\alpha}$, a

prostaglandin which is thought to act by a pathway affecting cytochrome P-450, caused a vasoconstrictive response similar to hypoxia. Metyrapone also reduced this response (lower right panel), suggesting specificity of action. These results are consistent with our hypothesis that the desaturated form of cytochrome P-450 is responsible for the pulmonary vascular response to hypoxia.

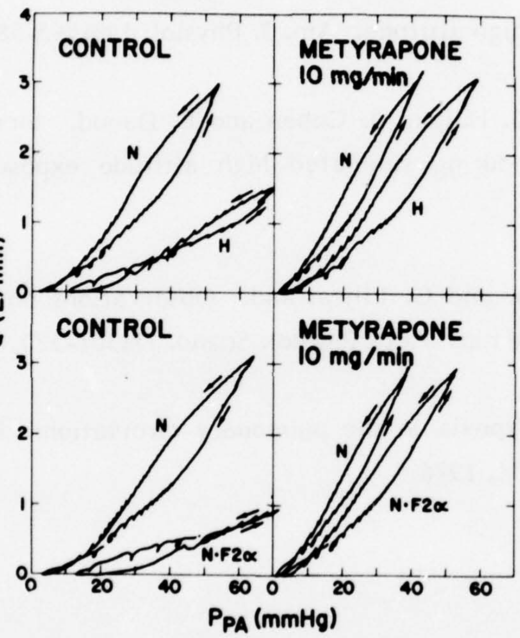


Figure 1. Effects of metyrapone on the relationships between pulmonary arterial pressure ($P_{PA}$) and flow ($\dot{Q}$) during normoxia (N), hypoxia (H) and prostaglandin $F2_{\alpha}$ administration.

## Presentations:

Sylvester, J. T. and C. McGowan. The effect of inhibitors of cytochrome P-450 on hypoxic pulmonary vasoconstriction. Presented, Annual Meeting, FASEB, Chicago, IL, 4 April 1977. (Fed. Proc. 36:535, 1977).

## Publications:

None.

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(81026)

| RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY | | 1. AGENCY ACCESSION* | 2. DATE OF SUMMARY* | REPORT CONTROL SYMBOL |
|---|---|---|---|---|
| | | DA OB 6133 | 77 10 01 | DD-DR&E(AR)636 |

| 3. DATE PREV SUM'RY | 4. KIND OF SUMMARY | 5. SUMMARY SCTY* | 6. WORK SECURITY* | 7. REGRADING* | 8a. DISB'N INSTR'N | 8b. SPECIFIC DATA-CONTRACTOR ACCESS | 9. LEVEL OF SUM |
|---|---|---|---|---|---|---|---|
| 77 09 02 | D. Change | U | U | NA | NL | [X] YES [ ] NO | A. WORK UNIT |

| 10. NO./CODES:* | PROGRAM ELEMENT | PROJECT NUMBER | TASK AREA NUMBER | WORK UNIT NUMBER |
|---|---|---|---|---|
| a. PRIMARY | 6.11.01.A | 3A161101A91C | 00 | 026 |
| b. CONTRIBUTING | | | | |
| c. CONTRIBUTING | | | | |

11. TITLE (Precede with Security Classification Code)* (U) Heat production and heat loss in chronic overweight as a function of endocrine patterns (22)

12. SCIENTIFIC AND TECHNOLOGICAL AREAS*
012900 Physiology

| 13. START DATE | 14. ESTIMATED COMPLETION DATE | 15. FUNDING AGENCY | 16. PERFORMANCE METHOD |
|---|---|---|---|
| 75 03 | CONT | DA | C. In-House |

17. CONTRACT/GRANT
a. DATES/EFFECTIVE: EXPIRATION:
b. NUMBER:* NOT APPLICABLE
c. TYPE: d. AMOUNT:
e. KIND OF AWARD: f. CUM. AMT.

| 18. RESOURCES ESTIMATE | | a. PROFESSIONAL MAN YRS | b. FUNDS (In thousands) |
|---|---|---|---|
| FISCAL YEAR | PRECEDING 77 | .7 | 27.3 |
| | CURRENT 78 | .1 | .4 |

19. RESPONSIBLE DOD ORGANIZATION
NAME:* USA RSCH INST OF ENV MED
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20. PERFORMING ORGANIZATION
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TELEPHONE: 955-2831
SOCIAL SECURITY ACCOUNT NUMBER:
ASSOCIATE INVESTIGATORS DANFORTH, Elliot, M.D.
NAME: 090-26-2209; Un of VT College of Med
NAME: Tel:(802) 656-2530 DA

21. GENERAL USE
Foreign Intelligence Not Considered

22. KEYWORDS (Precede EACH with Security Classification Code)
(U)Basal Metabolic Rate;(U)Heat Production;(U)Metabolic Regulation;(U)Thyroid Function

23. TECHNICAL OBJECTIVE.* 24. APPROACH. 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)

23. (U)Evaluate the thermogenic responses to ingestion of excess carbohydrate and/or fat by normal individuals, "easy or hard gainers," and those with distinct overweight problems. Understanding the mechanisms involved could extend cold tolerance by indicating ways of obtaining increased heat production. Collaborative study combines our heat production/loss expertise with endocrinology expertise at Univ. of Vermont Clinical Research Unit.

24. (U)Measure heat production and loss responses pre- and post-prandially before and after a 3-week hyperalimentation of approximately 2000 kcal per day. Temperature and heat production measurements will be made at USARIEM, overfeeding and endocrine assays at the Univ. of VT Med. Center under an NIH protocol.

25. (U)76 10 - 77 09 Three collaborative studies have been performed on groups of normal men (N=5 or 6) overfed 1300 kcal/day of fat, 1300 kcal/day of carbohydrate or 900 kcal/day of protein for periods of 18 days. Preliminary synthesis of the results suggests that ingestion of excess calories of all three components produces a detectable elevation of basal and resting pre- and post-prandial metabolic heat production which was also detectable 24 hours following withdrawal of the supplementary calories. This enhanced metabolic heat production does not seem to be further increased by exercise. Although protein overfeeding resulted in the greatest weight gain per kcal fed, overfeeding did not appear to result in less efficient weight gains (gms/kcal) with carbohydrate than with fat, as originally reported, perhaps reflecting the continued availability of unfilled fat cells after these few weeks of overfeeding. Circulating levels of $T_4$ were unaffected; $T_3$ levels increased significantly, 17% with protein, 29% with fat and 25% with carbohydrate while $rT_3$ levels fell only insignificantly with fat (-2%), but significantly with carbohydrate(-15%) and protein (-23%).

*Available to contractors upon originator's approval.

DD FORM 1 MAR 68 1498 PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE. DD FORMS 1498A, 1 NOV 65 AND 1498-1, 1 MAR 68 (FOR ARMY USE) ARE OBSOLETE.



* U.S. GPO: 1974-540-843/8691

| | |
|---|---|
| Program Element: | 6.11.01.A IN-HOUSE LABORATORY INDEPENDENT RESEARCH |
| Project: | 3A161101A91C In-House Laboratory Independent Research |
| Work Unit: | 026 Heat Production and Loss in Chronic Overweight as a Function of Endocrine Patterns |
| Study Title: | Hypermetabolic Response to Excess Calories in Normal Men |
| Investigators: | Richard L. Burse, Sc.D. and Ralph F. Goldman, Ph.D., in collaboration with Eliot Danforth, Jr., M.D., Ethan A. H. Sims, M.D., David C. Robbins, M.D. and Edward S. Horton, M.D. (University of Vermont) |

Background:

Previous studies (1,2,6,7,8,) have shown that overfeeding of carbohydrate (CHO) for periods ranging from 1-3 weeks results in metabolic heat production which is in excess of that expected from the increases in body weight. However, when fat is overfed for prolonged periods, metabolic heat production is not in excess of that expected as an accompaniment to the weight gain. Because the various studies comparing excess intake of fat or CHO calories were conducted at different times, one cannot be assured that conditions were controlled to the extent that the studies were strictly comparable. Accordingly, the heat production and heat loss responses were measured pre- and post-prandially before and after a 3-week overfeeding of either fat or CHO and a 2-week overfeeding of protein. The hypothesis was that ingestion of excess CHO calories results in greater thermogenesis, with correspondingly lower weight gain, than ingestion of the same number of calories as fat or protein.

Progress:

Initially a group of six subjects were maintained on an isocaloric diet for 10-14 days at the University of Vermont Medical Center. Their thermogenic responses at rest and during work were evaluated at US Army Research Institute of Environment Medicine, (USARIEM), following which they returned to Vermont for a

3-week period of overfeeding ~1300 kcal/day either CHO or fat calories (3 subjects on each diet). They then returned to USARIEM for the post-test of their thermogenic responses. To insure repro-ducibility of findings, and an adequate sample size, the study was replicated on another group of 5 subjects (3 overfed CHO, 2 overfed fat). The effect of overfeeding protein (~1000 kcal/day) for 14 days was assessed in a separate group of 5 subjects.

The study involved measurements of heat production - heat loss, effects on respiratory responses, RQ and metabolic measures. Dietary intake, measures and tests of thyroid hormone involvement were conducted by Dr. Eliot Danforth and his associates at the University of Vermont Medical Center using radioactive tracers and blood analysis to determine serum concentrations, production rates, metabolic clearance rates, fractional turnover rates and volume of distribution of thyroxine ($T_4$), triiodothyronine ($T_3$) and serum concentrations of reverse $T_3$ ($rT_3$) before and after overfeeding.

All subjects showed gains in weight after the overfeeding period. Table 1 shows length of overfeeding period and group averages of excess daily intake, overall weight gain and daily weight gain. There were marked differences in the amount of weight gained on each dietary constituent. Protein resulted in the greatest overall weight gain, despite it being overfed in less quantity and for a shorter length of time than the other constituents. The average daily gain on protein was 1.8 times that on fat and 2.1 times that on CHO. On a per calories basis, protein was 2.5 times as effective as fat, and 2.9 times as CHO in inducing weight gain.

Table 1. Duration and Amount of Overfeeding Carbohydrate (CHO), Fat or Protein and Resultant Weight Gains

| | CHO | FAT | PROTEIN |
|---|---|---|---|
| Overfeeding duration (dy) | 18 | 18 | 14 |
| Amount overfed (kcal/dy) | 1373 | 1338 | 977 |
| Total weight gain (kg) | 3.5 | 3.9 | 5.6 |
| Daily gain (kg/dy) | 0.19 | 0.21 | 0.40 |

TABLE 2. MEAN BASAL METABOLIC RATE ($W/M^2$) WITH ASSOCIATED STANDARD ERROR AND PERCENT CHANGE FROM CONTROL (Δ%).

| OVERFED COMPONENT | EXCESS (KCAL/DY) | N | CONTROL | OVERFED ON SUPPL. | OVERFED NO. SUPPL. | RECOVERY |
|---|---|---|---|---|---|---|
| PROTEIN | 977 | 5 | 43.0 ± 1.8 | 50.2 ± 1.1 | 46.2 ± 1.3 | 44.3 ± 1.1 |
| Δ% | | | | 16.9* | 7.5* | 3.1 |
| FAT | 1338 | 5 | 48.5 ± 1.2 | 53.1 ± 1.2 | 52.7 ± 2.1 | - |
| Δ% | | | | 9.5 | 8.7 | |
| CHO | 1373 | 6 | 45.8 ± 1.4 | 49.2 ± 1.4 | 50.3 ± 2.0 | - |
| Δ% | | | | 7.4 | 9.8 | |

* = $P < 0.05$

Average basal metabolic rate (BMR) in the control and overfed states are shown in Table 2. Protein showed the only significant effect, increasing BMR nearly 17% after overfeeding. Both fat and CHO changed BMR in the same direction, but the effect could not be shown to be statistically significant. When the assessments in the overfed state were repeated 24 hours after supplementation was stopped, the effect of protein was still present at about one-half its former level, and still showed significance. Fat and CHO showed effects of the same magnitude, but again these could not be shown to be statistically significant. However, all the data seem to point to the conclusion that there was an increase in basal metabolism during active overfeeding (greatest for protein); this was not the result of carryover from the larger meal the night before, as it persisted even when only the control meals had been fed for 24 hours. Whether or not these increases in BMR were found to be statistically significant appeared to be just a matter of getting a large enough sample to offset random variability, as the magnitude of the changes appeared to be relatively constant, irrespective of the dietary constituent overfed.

TABLE 3. MEAN RESTING METABOLIC RATE ($W/M^2$) WITH ASSOCIATED STANDARD ERROR AND PERCENT CHANGE FROM CONTROL ( $\Delta$ %).

| OVERFED COMPONENT | EXCESS (KCAL/DY) | N | CONTROL | OVERFED ON SUPPL. | OVERFED NO SUPPL. | RECOVERY |
|---|---|---|---|---|---|---|
| PROTEIN | 977 | 5 | 46.2 ± 1.4 | 60.5 ± 1.4 | 49.5 ± 1.6 | 48.0 ± 1.4 |
| $\Delta$% | | | | 31.0** | 7.1 | 3.9 |
| FAT | 1338 | 5 | 50.0 ± 1.2 | 60.4 ± 7.3 | 56.9 ± 1.9 | - |
| $\Delta$% | | | | 20.8* | 13.8* | |
| CHO | 1373 | 6 | 47.2 ± 2.6 | 57.4 ± 2.1 | 59.6 ± 4.3 | - |
| $\Delta$% | | | | 21.6* | 26.3* | |

** = $P < 0.01$
* = $P < 0.05$

Table 3 shows post-absorptive resting metabolic rates to have been affected in the same way, but to an even greater extent. The increased basal rates after overfeeding were clearly reflected in the increased resting metabolism, and reinforce the conclusions of a real and persistent change in metabolism after overfeeding, which endure after an overnight fast.

TABLE 4. PERCENTAGE CHANGES IN SERUM LEVELS AND KINETICS OF $T_4$. NO CHANGES SIGNIFICANT ($p > 0.05$).

| PARAMETER | OVERFED COMPONENT CHO | FAT | PROTEIN | ALL DIETS POOLED |
|---|---|---|---|---|
| SERUM CONCENTRATION | -1 | +3 | -3 | -1 |
| PRODUCTION RATE | -2 | -5 | -6 | -5 |
| MET. CLEARANCE RATE | +2 | -8 | -5 | -5 |
| FRACTIONAL TURNOVER RATE | +1 | -1 | +5 | +1 |
| VOLUME OF DISTRIBUTION | -4 | -8 | -8 | -7 |

These elevations were associated with changes $T_3$ and $rT_3$, but not $T_4$. Table 4 shows percentage changes in serum levels, metabolic clearance rate, production rate, fractional turnover rate and volume of distribution of $T_4$. There were no significant changes with overfeeding any dietary component.

TABLE 5. PERCENTAGE CHANGES IN SERUM LEVELS OF $rT_3$ AND $T_3$, AND KINETICS OF $T_3$

| PARAMETER | CHO | FAT | PROTEIN | ALL DIETS POOLED |
|---|---|---|---|---|
| | OVERFED COMPONENT | | | |
| $rT_3$ SERUM CONC. | -15 ** | -2 | -23 ** | -13 ** |
| $T_3$ SERUM CONC. | +25 ** | +29 ** | +17 ** | +23 ** |
| PRODUCTION RATE | +82 ** | +74 ** | +71 ** | +76 ** |
| MET. CLEARANCE RATE | +43 ** | +32 ** | +33 ** | +36 ** |
| FRACTIONAL TURN-OVER RATE | +2 | +3 | +20 ** | +8 * |
| VOLUME OF DISTRIBUTION | +39 ** | +26 ** | +11 | +22 ** |

* = $p < 0.05$; ** = $p < 0.01$

Table 5 shows the changes in $T_3$ with their significance. Serum $T_3$ increased from 17% to 29% above control levels with no significant differences between the dietary component that was overfed; the overall average being 23%. Average metabolic clearance rate increased 36%, while the fractional turnover rate increased 8%. The production rate increased 76%. Volume of distribution also increased 22%. Complementary decreases in serum levels of $rT_3$ of 13% were observed. There may have been an effect of the number of calories overfed, in that the protein group showed a consistently lower magnitude of change in $T_3$, but the differences between groups could not be shown to be significant. $T_3$ resin binding showed no changes with overfeeding, indicating no change in the amount of thyroid hormone bound to serum protein.

Three conclusions follow from the above results:

1. There is an increase in basal and resting metabolism in response to overfeeding either CHO, fat, or protein to normal weight individuals, which is most easily demonstrated with protein. There is no concomitant increase in exercise metabolism with any dietary constituent. This contrasts with earlier results on spontaneously obese individuals who showed a 25% increase in exercise metabolism

above that predicted from their weight gain after being overfed CHO (2).

2. The duration and extent of the thermic effect (SDA) of meals is enhanced by overfeeding and some of the response persists after dietary supplementation is stopped.

3. The changes in thyroid hormone levels and kinetics with overfeeding agree in direction with the changes in metabolism. Whether the changes are causally related remains to be determined. At present it is clear that these observations are opposite to the changes in the same parameters seen during starvation, when resting metabolism is diminished at the same time peripheral conversion of $T_4$ to $T_3$ is decreased.

The changes in $T_3$ and $rT_3$ with no change in $T_4$ therefore suggest that there was an increase in the peripheral conversion of $T_4$ to $T_3$ as a result of the overfeeding of calories per se, rather than any one specific component of the diet. These thyroid changes appear to be associated with slight elevations in resting metabolism, but not with any large wastage of surplus calories. The observed levels of change in metabolism and thyroid activity are not consonant with the hypothesis that metabolic rate is controlled by the amount of $T_3$ that is released in the periphery. If this were so, much greater changes in basal and resting metabolic rates in response to the increased production of $T_3$ would have been observed.

At present, no further experimentation is planned. Completion of data analysis and manuscript preparation for open literature publication remain to be accomplished; partial reports of this research have already appeared (3,4,5).

Presentations:

None.

Publications:

None.

## LITERATURE CITED

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3. Burse, R. L., R. F. Goldman, E. Danforth, Jr., E. S. Horton and E. A. H. Sims. Effect of excess carbohydrate and fat intake on resting metabolism. Fed. Proc. 36:546, 1977.

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6. Durnin, J. V. G. A. and N. Norgan. Variations in total body metabolism during "overfeeding" in man. J. Physiol. (London) 202:106P, 1969.

7. Goldman, R. F. Bioenergetics and the response to overfeeding. In: Obesity in Perspective, Vol II, Fogarty International Series on Preventive Medicine, G. A. Bray, (ed.) Washington, D.C., U.S. Government Printing Office, 1976.

8. Miller, D. S., P. Mumford and M. J. Stock. Gluttony 2: Thermogenesis in overeating man. Am. J. Clin. Nutr. 20:1223-1229, 1967.

| | |
|---|---|
| Program Element: | 6.11.01.A IN-HOUSE LABORATORY INDEPENDENT RESEARCH |
| Project: | 3A161101A91C In-House Laboratory Independent Research |
| Work Unit: | 026 Heat Production and Heat Loss in Chronic Overweight as a Function of Endocrine Patterns |
| Study Title: | Heat Production and Heat Loss in Individuals Considered "Easy" as Opposed to "Hard" Gainers |
| Investigators: | Ralph F. Goldman, Ph.D. and Richard L. Burse, Sc.D. in collaboration with the University of Vermont Clinical Research Center |

Background:

It has been shown in previous work by Miller et al. (6), Durnin and Norgan (3), and more recently in a preliminary phase of this investigation by Goldman et al. (5), that overfeeding of carbohydrate for a prolonged period can increase heat production and metabolism beyond the normal increase expected simply from the accompanying gain in body size.

This study involved four subjects, all of whom have a history of obesity and were considered "easy-gainers." Since previous tests were on more normal subjects, we questioned whether this response to carbohydrate overfeeding exists in the obese, or if absence of a mechanism for excess caloric consumption is a contributory cause of these subjects' obesity.

In seeking to determine a mechanism for this effect, we studied heat production-heat loss; RQ factors; respiratory responses; corrected metabolic measures, in conjunction with our studies, Dr. Eliot Danforth, Jr. (University of Vermont Medical Center) is conducting tests on hormone production, particularly involvement of the thyroid, using radioactive tracers and radioassay procedures. The four subjects were tested on two occasions, separated by 18 days of carbohydrate overfeeding of 2000 kcal per day. As a result of this overfeeding, body weight increased 4%, surface area 27%, and basal metabolism 15%, exceeding that expected from increased body size. Working heat production increased 16%;

of this increase, the increased basal metabolism accounted for about 1/4 and the energy cost of moving the increased body weight 1/5. The remaining 55% of the increase is apparently the same thermogenic response to intake of excess calories previously seen during work by individuals of normal weight.

Post-prandial resting metabolic rates were consistently (but not statistically significantly) higher after overfeeding. Basal and resting respiratory quotients (RQ) did not change, but RQ during work increased from 0.79 to 0.93, suggesting an increased carbohydrate metabolism. There was definitely increased turnover of $T_3$ in the body after overfeeding, and a suggestion of increased peripheral conversion of $T_4$ to $T_3$, which support the metabolic findings of increased basal and working energy expenditure.

Progress:

The preliminary assays of thyroid hormone have been confounded by the hyperlipidemia of these overweight subjects. During the past year, the thyroid assay technique has been refined to correct for the hyperlipidemia. All sera will now be reanalysed to confirm the original findings.

The metabolic results from these overweight subjects were compared with those of 6 normal weight controls also overfed carbohydrate for 3 weeks. The normal weight men did not show a significantly increased metabolism during exercise above that required by the added body weight (4), as was true of the overweight men. This suggests that the normal weight individuals may have stored the excess calories in those fat cells capable of doing so, while the overweight individuals' fat cells may have been unable to store more energy, forcing them to metabolize the excess. Preliminary reports have been presented in the literature (1,2).

Future Plans:

Repeat thyroid hormone assays are scheduled to be performed at the University of Vermont Clinical Research Center. Additional assays of insulin, glucagon, HGH and TSH will also be undertaken to determine their responses to the overfeeding regime. This study will be terminated after the results are written up.

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1. Burse, R. L., R. F. Goldman, W. Crowley, E. Danforth, Jr., and E. A. H. Sims. Elevated metabolism in obese males after excess carbohydrate intake. Fed. Proc. 35:402, 1976.

2. Burse, R. L., R. F. Goldman, E. Danforth, Jr., E. S. Horton and E. A. H. Sims. Effect of excess carbohydrate and fat intake on resting metabolism. Fed. Proc. 36:546, 1977.

3. Durnin, J. G. V. A. and N. Norgan. Variations in total body metabolism during overfeeding in man. J. Physiol, (London) 202:106P, 1969.

4. Givoni, B., and R. F. Goldman. Predicting metabolic energy cost. J. Appl. Physiol. 30:429-433, 1971.

5. Goldman, R. F. Bioenergetics and the response to overfeeding. In: Obesity in Perspective, Fogarty International Center Series on Preventive Medicine, Vol. II, G. A. Bray (ed.) Washington, D. C.; U.S. Government Printing Office, 1976.

6. Miller, D. S., P. Mumford and M. J. Stock. Gluttony, 2: Thermogenesis in overeating man. Am. J. Clin. Nutr. 20:1223-1229, 1967.

(81027)

**RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY**

| 1. AGENCY ACCESSION* | 2. DATE OF SUMMARY* | REPORT CONTROL SYMBOL |
|---|---|---|
| DA OB 6136 | 77 10 01 | DD-DR&E(AR)636 |

| 3. DATE PREV SUM'RY | 4. KIND OF SUMMARY | 5. SUMMARY SCTY* | 6. WORK SECURITY* | 7. REGRADING* | 8a. DISB'N INSTR'N | 8b. SPECIFIC DATA-CONTRACTOR ACCESS | 9. LEVEL OF SUM |
|---|---|---|---|---|---|---|---|
| 76 10 01 | H.Terminated | U | U | NA | NL | [X] YES [ ] NO | A. WORK UNIT |

| 10. NO./CODES:* | PROGRAM ELEMENT | PROJECT NUMBER | TASK AREA NUMBER | WORK UNIT NUMBER |
|---|---|---|---|---|
| a. PRIMARY | 6.11.01.A | 3A161101A91C | 00 | 027 |
| b. CONTRIBUTING | | | | |
| c. CONTRIBUTING | | | | |

11. TITLE (Precede with Security Classification Code)*

(U) The Squirrel Monkey as a Model for Peripheral Cooling (22)

12. SCIENTIFIC AND TECHNOLOGICAL AREAS*

012900 Physiology 016200 Stress Physiology

| 13. START DATE | 14. ESTIMATED COMPLETION DATE | 15. FUNDING AGENCY | 16. PERFORMANCE METHOD |
|---|---|---|---|
| 76 04 | 77 09 | DA | C. In-House |

17. CONTRACT/GRANT

a. DATES/EFFECTIVE: EXPIRATION:

b. NUMBER:* NOT APPLICABLE

c. TYPE: d. AMOUNT:

e. KIND OF AWARD: f. CUM. AMT.

| 18. RESOURCES ESTIMATE | | a. PROFESSIONAL MAN YRS | b. FUNDS (In thousands) |
|---|---|---|---|
| FISCAL YEAR | PRECEDING 77 | .5 | 17 |
| | CURRENT | | |

19. RESPONSIBLE DOD ORGANIZATION

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ASSOCIATE INVESTIGATORS

NAME:

NAME:

DA

21. GENERAL USE

Foreign Intelligence Not Considered

22. KEYWORDS (Precede EACH with Security Classification Code) (U) Cold Induced Vasodilatation; (U) CIVD; (U) Thermoregulation; (U) Peripheral Blood Flow; (U) Squirrel Monkey

23. TECHNICAL OBJECTIVE,* 24. APPROACH, 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)

23. (U)The aim of this study is to evaluate the feasibility of using the monkey as a model for peripheral thermoregulation in response to cooling.

24. (U)The peripheral response to local cooling will be assessed by blood flow (plethysmograph) and temperature (thermocouple) measurements. Alterations in the rate of cooling and/or production of CIVD will be examined. The squirrel monkey is being used because its thermoregulation is similar to that of humans and the anatomical relationships of the monkey tail to the human hand is closer than a dog's or cat's paw would be. The types of studies being considered are pressure-flow relationships, nutritive flow vs. bulk flow, and the effects of flow-alterating drugs during cooling.

25. (U) 76 06 77 09 The experimental work has been suspended awaiting the completion of a cooling chamber for isolation of the monkey tail. Future work will be conducted under agency assession number DA OA 6142.

*Available to contractors upon originator's approval.

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| Program Element: | 6.11.01.A IN-HOUSE LABORATORY INDEPENDENT RESEARCH |
| Project: | 3A161101A91C In-House Laboratory Independent Research |
| Work Unit: | 027 The Squirrel Monkey as a Model for Peripheral Cooling |
| Study Title: | The Squirrel Monkey as a Model for Peripheral Cooling |
| Investigator: | Donald E. Roberts, Ph.D. |

## Background:

The requirements for an animal model for thermoregulation include an active vasomotor response, a thermoneutral range and central hypothalamic control. The squirrel monkey fulfills these requirements (1,2). It has been shown by Stitt and Hardy (2) that the squirrel monkey has a thermoneutral range from 25$^{\circ}$- 35$^{\circ}$C. The amount of surface area available for sweating (palms of hands and soles of feet) along with this wide thermoneutral range and a high tissue conductance indicates a predominance of vasomotor control for thermoregulation (2).

Stitt and Hardy have shown that the tail and the feet are important heat dissipating organs in warm environments with the tail being more active at the lower temperature range of the thermoneutral zone. Since the tail and feet are important thermoregulating organs and vasomotion appears to be the primary mechanism, these organs should have a high probability of exhibiting a cold induced vasodilation response. The purpose of this study is to determine if the squirrel monkey may be used as an animal model for cold induced vasodilation.

## Progress:

The experimental work has been suspended awaiting the completion of a cooling chamber capable of isolating the monkey tail and of allowing changes in the ambient temperature within the chamber.

## Presentations:

None

## Publications:

None

(81028)

| RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY | 1. AGENCY ACCESSION* DA OB 6137 | 2. DATE OF SUMMARY* 77 10 01 | REPORT CONTROL SYMBOL DD-DR&E(AR)636 |
|---|---|---|---|

| 3. DATE PREV SUM'RY | 4. KIND OF SUMMARY | 5. SUMMARY SCTY* | 6. WORK SECURITY* | 7. REGRADING* | 8a. DISB'N INSTR'N | 8b. SPECIFIC DATA-CONTRACTOR ACCESS | 9. LEVEL OF SUM |
|---|---|---|---|---|---|---|---|
| 77 09 02 | D. Change | U | U | NA | NL | ☒ YES ☐ NO | A. WORK UNIT |

| 10. NO./CODES:* | PROGRAM ELEMENT | PROJECT NUMBER | TASK AREA NUMBER | WORK UNIT NUMBER |
|---|---|---|---|---|
| a. PRIMARY | 6.11.01.A | 3A161101A91C | 00 | 028 |
| b. CONTRIBUTING | | | | |
| c. CONTRIBUTING | | | | |

11. TITLE (Precede with Security Classification Code)*

(U)Physiologic Correlates of Induced Severe Hyperthermia in Man (22)

12. SCIENTIFIC AND TECHNOLOGICAL AREAS*

012900 Physiology

| 13. START DATE | 14. ESTIMATED COMPLETION DATE | 15. FUNDING AGENCY | 16. PERFORMANCE METHOD |
|---|---|---|---|
| 76 10 | CONT | DA \| NIH | C. In-House |

17. CONTRACT/GRANT

a. DATES/EFFECTIVE: EXPIRATION:
b. NUMBER:* NOT APPLICABLE
c. TYPE: d. AMOUNT:
e. KIND OF AWARD: f. CUM. AMT.

| 18. RESOURCES ESTIMATE | | a. PROFESSIONAL MAN YRS | b. FUNDS (In thousands) |
|---|---|---|---|
| FISCAL YEAR | PRECEDING 77 | .5 | 11 |
| | CURRENT 78 | .5 | 0 |

19. RESPONSIBLE DOD ORGANIZATION

NAME:* USA RSCH INST OF ENV MED
ADDRESS:* Natick, MA 01760

RESPONSIBLE INDIVIDUAL
NAME: DANGERFIELD, HARRY G., M.D., COL, MC
TELEPHONE: 955-2811

20. PERFORMING ORGANIZATION

NAME:* USA RSCH INST OF ENV MED
ADDRESS:* Natick, MA 01760

PRINCIPAL INVESTIGATOR (Furnish SSAN if U.S. Academic Institution)
NAME:* GOLDMAN, Ralph F. Ph.D.
TELEPHONE: 955-2831
SOCIAL SECURITY ACCOUNT NUMBER: 030-20-2988
ASSOCIATE INVESTIGATORS BULL, Joan, M.D., NIH
NAME: National Cancer Institute
NAME: (301) 496-6919 DA

21. GENERAL USE

Foreign Intelligence Not Considered

22. KEYWORDS (Precede EACH with Security Classification Code)

(U)Hyperthermia;(U)Critical Thermal Maximum;(U)Esophageal Temperature;(U)Cancer

23. TECHNICAL OBJECTIVE.* 24. APPROACH, 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)

23. (U)Evaluate phyisological effects of 107 ± 1°F body temperature, considered the threshold for heatstroke, in collaborative study with National Institutes of Health. USARIEM focus is on mechanisms involved in heatstroke; NIH proposes studying therapeutic effects of such body temperatures.

24. (U)USARIEM expertise at less severe levels of hyperthermia (104°F temperatures) will be involved in a four-phase study: (1) copper manikin evaluation of systems proposed for inducing hyperthermia; (2) study of physiological responses of normal soldiers during rapid body temperature elevation to 103°F, followed by a 30-minute holding period and a cooldown; (3) development of a model which correctly predicts critical responses observed in (2); (4) participation in NIH clinical trials to 107 ± 1°F level, to contribute our experience in measuring and regulating hyperthermia, provide maximal safety, and gather data for improving prediction of the correlates of extreme body temperature elevation.

25. (U)A proposed circulating hotwater suit for inducing 107 ± 1°F body temperature was evaluated using a sectional heated manikin; the results suggested that body temperature could be raised to this level without risk of burning a man, but that the operating procedure needed revision to reduce heating time, and supplementary rapid cooling was required. Nine volunteers were heated at USARIEM to the 103 ± 1°F level and, after further procedural modifications, five patients at National Cancer Institute were heated to 107 ± 1°F and held one hour without sequelae, except for a modest elevation of serum enzymes. Data to date, and other ovservations, suggest that heatstroke results from a combination of elevated temperature and exposure time, rather than a critical threshold temperature alone. A mathematical model has been developed which appears to have been validated by animal studies under another work unit.

*Available to contractors upon originator's approval

DD FORM 1 MAR 68 1498 PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE. DD FORMS 1498A, 1 NOV 65 AND 1498-1, 1 MAR 68 (FOR ARMY USE) ARE OBSOLETE.



* U.S. GPO: 1974-540-843/8691

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Program Element: 6.11.01.A IN-HOUSE LABORATORY INDEPENDENT RESEARCH

Project: 3A161101A91C In-House Laboratory Independent Research

Work Unit: 028 Physiologic Correlates of Induced Severe Hyperthermia in Man

Study Title: Copper Man Evaluation of Hyperthermia Induction Suit

Investigators: George F. Fonseca and Ralph F. Goldman, Ph.D.

Background:

The National Cancer Institute, as part of a collaborative study, requested the assistance of USARIEM in evaluating a circulating warm water suit and controller for its utility in heating and maintaining a human body in extreme hyperthermia (T $\cong 42^{o}C$) during cancer therapy. Before initiating study of human hyperthermia, a copper manikin evaluation of *this National Cancer Institute Body Heating and* Cooling Apparatus (HCA-II), with its associated tubing garment and foam insulating garment was performed. Both unheated and heated manikin evaluations were made using a manikin with six sections, vis: head, torso, arms, hands, legs and feet. The unheated manikin was used to measure the rate of change (increase or decrease) in skin temperature as a result of the HCA-II supplied (heating or cooling) water flow through the tubing of the tubing garment; the resulting skin temperatures at the different "control stages" of the HCA-II were also measured. The electrically heated manikin was used to determine: (a) the individual sectional and overall total manikin heat loss (electrical watts) as a function of control stage; (b) the sectional and total insulation values of the tubing garment plus the foam insulating garment; (c) the heat transfer from the skin of the manikin to the water flowing in the tubing of the garment.

Progress:

Limited studies were conducted with the manikin electrically unheated to ascertain the increase (or decrease) in manikin skin temperature as heating (or cooling) water flowed through the tubing of the garment. During the heating phase,

the manikin skin temperature increased from 30°C to 45°C, requiring about 45 minutes to reach this level; after approximately 85 minutes of cooling, skin temperature was at 31°C, having decreased rather slowly, at a rate of 1°C every 3 or 4 minutes during the first 30 minutes of cooling. These results suggested an unusually long warming period for human studies (and probably an unacceptably slow cooling rate) since a human's esophageal and rectal temperature responses will still further lag behind these slow skin temperature changes.

Manikin skin temperatures were evaluated at the seven different control stage settings. With the esophageal temperature setting on the HCA-II controller at 42°C, the average manikin skin temperature was maintained at 41.5°C at the #1 control stage setting, and at 33.7°C at the #7 control stage setting; setting #2 corresponded to a skin temperature of 39.2°C, #3 to 38.1°C, and #4 and #5 to 36.5°C; setting #6 could not be held constant across the HCA control range of 39.1 to 39.4 and, therefore, could not be evaluated in this fashion. There appeared to be very little effective heating of the head section at any of the control stage settings. The torso, arms, and hands were maintained within 1°C of each other; the legs were 1-2°C hotter than these three manikin sections. The feet were 2-3.5°C lower than the average manikin skin temperature. The lowest value of water inlet temperature measured during cooling was 29.6°C. The suit inlet temperature of the water measured during collection of the data were: for control stage #1, 45.6°C; #2, 42.9°C; #3, 41.9°C; #4/#5, 40.3°C; and for #6/#7, 36.7°C; these levels should not burn human subjects, but the 45.6°C stage #1 level approaches the pain threshold of human skin. Therefore, direct skin contact with the circulating fluid should be avoided.

Sectional and total manikin heat losses (electrical watts) were examined as a function of control stage settings #1 through #7. At control stage setting #1, the heat transferred to the manikin from the hot water circulating in the tubing garment was sufficient to maintain skin temperature at the manikin control temperature of 43°C without any electrical heat being supplied to the manikin over the torso, arms, hands, and legs. However, the head and feet were essentially unheated by the hot water circulating in the tubing garment and approximately 25 watts were required by these sections (19 to the head and 6 to the feet) to maintain their 43°C skin temperature. At setting #2, 52 watts were required to maintain

the 43°C skin temperature overall, at #3,69 watts and at #4,5,6 and 7,100 watts. Thus, given a human subject with the usual resting 100 watts of heat production, skin temperature could be as high as 43°C at any of the four highest control levels (i.e., at stage #4,5,6 or 7) even though water temperature at these settings is 40°C or lower; of course, if the system were functioning correctly, skin temperatures would generally be close to the water temperature appropriate to the particular control stage setting.

Sectional and total insulation (clo) values for the tubing garment plus foam insulating garment with hood, without water flow through the tubing was then evaluated. The manikin, on a rolling cot, was placed in a chamber controlled at an air temperature of 21.6°C. Without any flow of water, insulation was greatest over the torso and legs, and least over the head and feet. The overall value of 2.7 clo indicates that a human, similarly encased, will lose only 2.4 watts/$m^2 \cdot$ hr per °C difference between his skin and the ambient air temperature, even without water flow to the garment. For an average 70 kg man with $1.8m^2$ of surface area, producing 100 watts of metabolic heat, with a comfortable skin temperature initially at 33°C at a chamber temperature of 20°C, body heat storage would amount to some 44 watts, equivalent to a rise of about 0.6°C per hour in mean body temperature. Thus, if a human subject was initially too cool to trigger the flow of heated water from the HCA state #1 control (i.e., esophageal temperature initially much below 36.9°C) a long delay may be experienced before the HCA controller is activated; e.g., if initial esophageal temperature is 36.3°, nearly one hour of delay will occur before it reaches 36.9°C and triggers stage #1 heating.

Cooling was initiated from (heating) control stage settings #6/#7. After nearly 9 minutes of cooling, heat loss from the manikin reached a plateau; heat loss from manikin sections increased, and showed almost a 2.1 increase over the initial value (0 minutes of cooling) for the legs, 1.8 for the torso, 1.7 for the arms, and very little increase for the head, hands, and feet. The total heat transfer from the manikin increased from 154 watts to 269 watts or about 1.7 times the initial total manikin heat loss. The difference, some 115 watts, probably represents the maximum rate of heat removal possible with the HCA-II system from a subject with an elevated skin temperature of 43°C; as the skin temperature of a human subject would fall with such cooling, rather than be held at the 43°C which our

copper manikin maintained, the maximum cooling rate of a human would fall below the 115 watt rate with time. Such a cooling rate would reduce the body temperature of a 70 kg man by about 1.7°C per hour, which suggested that the maximum cooling available with the HCA-II system should be supplemented by an auxiliary cold water source to provide a truly "emergency" cooling capacity. Alternatively, a water spray, to be used directly over the patient, (inserted initially in the zipper gap in the suit until the suit could be removed) plus a high velocity fan should be made available for human studies.

Using the sectional and total clo values derived without water flow, the heat transfer from the skin (sk) of the manikin to the chamber environment (air), can be calculated in watts per degree Celsius temperature difference between manikin skin and air ($W/^{o}C_{sk\text{-}air}$). These values, together with the data given above on the sectional and total measured electrical watts supplied to the manikin during an *emergency cooling condition*, were used to calculate the heat transferred between the skin of the manikin and the cooling water (c.w.), in watts per degree Celsius temperature difference between the manikin skin temperature and the water temperature at the inlet to the tubing garment. These values showed that the largest heat transfer from the manikin skin to the cooling water occurred over the torso and legs, and the least (less than $1 W/^{o}C_{sk\text{-}c.w.}$) for the head, hands, and feet. It should be noted that the feet of the manikin were not directly covered by tubing as the system is configured currently.

Check temperature display readings at end of 8 hours of operating body heating and cooling apparatus were observed. The three check (HCA reference standard) temperature displays (CHK rectal and skin temperatures, CHK esophageal temperature, and CHK tumor temperature) should show 40.0°C ($\pm$ 0.2°C) when each of the three CHK switches are depressed. The 3 CHK switches were depressed at the end of 8 hours of operating the body heating and cooling apparatus. Chamber air temperature was generally 24°C, except for one day at 27°C and one day at 30°C; at these higher air temperatures, the temperature display for the CHK rectal and skin temperatures was greater than 1°C above the 40.4°C set point temperature. Out of the 33 readings taken, 13 were outside of the specified 40.0°C $\pm$ 0.2°C limits. The CHK esophageal display showed a reading of 39.4°C and the esophageal probe temperature reading was 38.6°C when the

esophageal probe was located in a 39.2°C water bath. The 38.6°C reading obtained indicated that the drift in checkpoint value affected all temperature measurements. Thus, if the checkpoint is 0.5°C low, all temperature measurements, control actions (stage 1-7, caution light, etc.) would also be in error by the same degree. This poses a distinct hazard to human subjects unless careful attention is paid to the checkpoint value, or this drifting is corrected. No external adjustment of checkpoints is possible; thus, an engineer would have to be on call to make any necessary corrections.

The findings of this biophysical evaluation of this National Cancer Institute Body Heating and Cooling Apparatus indicated that proposed physiological trials of this system could proceed with humans, after correction of the electrical drift of the temperature displayed. However, these findings suggested a lengthy start up time and that some supplementary means of emergency cooling must be provided.

Presentations:

None

Publications:

None

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| Program Element: | 6.11.01.A IN-HOUSE LABORATORY INDEPENDENT RESEARCH |
| Project: | 3A161101A91C In-House Laboratory Independent Research |
| Work Unit: | 028 Physiologic Correlates of Induced Severe Hyperthermia In Man |
| Study Title: | Hyperthermic Response to Heat Loads Generated by a Circulating Water Suit |
| Investigators: | Gaither D. Bynum, M.D., MAJ, MC, Kent B. Pandolf, Ph.D., George Fonseca, Ralph F. Goldman, Ph.D. |

Background:

Scientific literature over the last 110 years developed induced human hyperthermia both as a model for studying physiologic variables and as a therapeutic regimen. Busch in 1866 (2) and Burns in 1887 (1) describe both syphyllis and cancer remissions or cures after 1-4 days of 40°C fever associated with erysipelas. The National Institutes of Health were interested in induction of human hyperthermia as a possible treatment and/or therapy for cancer. Although core temperatures in excess of 41°C were to be evaluated at the National Institutes of Health, at USARIEM normal subjects in a pilot study of the system were exposed to lower core temperature elevations. The theory and technology of the automated hyperthermia induction system explored in this study were developed by the aircraft industry and incorporated into NASA extra vehicular suits to insure the thermal neutrality of astronauts (4); another configuration of the same technology was used to rewarm hypothermic divers (5). This technology had not previously been evaluated for the induction and maintenance of hyperthermic states. The system evaluated consisted of an insulated vinyl suit, through which hot water was circulated, and a control module (HCA-II). Esophageal, rectal, and three skin thermistors worn by the subject provided feedback signals to the control module. Within the control module, these signals were utilized to compare the subject's current thermal status relative to preset maximum or body temperatures and their rates of rise. The closed loop, constant flow of hot water (46°C, 6L/min) through the suit was generated by pumps in the control module. As esophageal temperature

approached the preset maximum, water temperature decreased to a temperature sufficient to maintain it at the preset maximum. In this way, body temperature may be maintained within 0.2°C of any selected temperature. Should the preset maximum temperature or rate of thermal loading be exceeded, a cool water source (24°C) could be automatically introduced into the suit and heating discontinued.

Progress:

All subjects underwent a physical examination prior to exposure. Age range was 19-22 yrs; exposure limits were heart rate (HR) 160 and/or rectal or esophageal temperature 39.2 ± 0.3°C, with a maximum rate of rectal temperature ($T_{re}$) rise 0.1°C/ min; in addition, no skin temperature was allowed to exceed 44°C. The HCA-II rectal and skin temperature monitoring system was duplicated, as a safety precaution, by a YSI rectal thermistor and three skin thermocouples interfaced with a Leeds and Northrup speedomax recorder. Immediately prior to heating, the two rectal thermistors were inserted approximately 10 cm; the HCA-II esophageal thermistor was placed to the level of the right atrium and placement was documented by X-ray; three skin thermocouples for the Leeds, Northrup and three HCA-II thermistors were affixed to the skin with tape, over areas of the chest, biceps, and thigh; twelve EKG leads were placed on the chest for determination of heart rate (HR) and monitoring of clinical electrocardiograms. The subject, clothed in a light cotton garment to minimize the possibility of discomfort or contact burns, was then asked to lie in a supine position in the suit. After a blood pressure cuff and magnetometer respiratory sensor were positioned, the hyperthermic suit was then closed about the subject. Esophageal temperature was elevated to 39.2 ± 0.3°C and held for 30 minutes and then 24°C water was introduced into the circuit as a cooling mode for 30 minutes. Temperatures were monitored continuously, and recorded and plotted "on line" by a 9810 Hewlett/Packard calculator plotter. Expired air samples were collected for calculation of metabolic rates. Heart rates, blood pressure and expired air samples were collected every six minutes.

Six of the nine subjects successfully completed the study. The heating rate of 1.9°C/hr for rectal and 2.1°C/hr for esophageal temperatures was approximately

50 percent less than that reported by Pettigrew, et al. (3) with hot wax immersion. Suit water temperatures of only 37.5 - 38.0°C sufficed to maintain maximum rectal and preset esophageal temperatures because of the "effective" 6 clo insulating barrier provided by the heating suit for the subject's own heat production. The data trend suggested a rise in metabolic rate (MR) with rising core temperatures. Other physiological measurements are given in Table 1.

TABLE I

Mean Values of Physiologic Variables for Six Healthy Men Heated to $T_{es}$[a] 39.3 ± 0.2°C

| | Initial | Begin Hold | Begin Cool | Term |
|---|---|---|---|---|
| RR | 13.3 ± 2.4 | 15.0 ± 4.7 | 17.7 ± 7.4 | 13.3 ± 3.9 |
| Sys BP | 111.5 ± 13.1 | 138.5 ± 19.3 | 129.5 ± 15.7 | 121.0 ± 19.9 |
| Dias BP | 67.5 ± 13.5 | 67.5 ± 12.1 | 62.5 ± 4.2 | 62.5 ± 2.7 |
| HR | 74.0 ± 5.3 | 116.2 ± 9.4 | 108.2 ± 9.8 | 99.0 ± 15.5 |
| $T_{es}$ | 36.5 ± 0.3 | 39.0 ± 0.1 | 38.9 ± 0.1 | 37.7 ± 0.3 |
| $T_{re}$ | 36.9 ± 0.4 | 39.1 ± 0.1 | 39.5 ± 0.1 | 39.0 ± 0.3 |

a - RR, respiratory rate breaths/min; Sys BP, systolic blood pressure mmHg; Dias BP, diastolic blood pressure mmHg; HR, heart rate beats/min; $T_{es}$, esophageal temperature, °C; $T_{re}$, rectal temperature, °C.

The heating times required were in accord with the projections from the copper man studies. Based upon these results with normal volunteers, a few auxiliary back-up approaches were recommended and it seemed safe to proceed with the NCI phase of the study, after some mathematical analysis and projections were developed based on these exposures to 39.2°C.

Presentations:

1. Bynum, G., K. B. Pandolf and R. F. Goldman, "Human Hyperthermia Induction: Comparison of Circulating Water Suit with Other Methods." Federation Proceedings, 36(3):512, 1977.

2. Bynum, G., K. B. Pandolf, R. F. Goldman and J. Bull, "A Comparison of Current Methodologies for Induction of Human Hyperthermia." Proceedings of the International Union of Physiological Sciences (Abstracts of Volunteer Papers), 13:112, 1977.

Publications:

None

## LITERATURE CITED


1. Burns, P. Die heilwirkung des erysipels auf geschwulste. Beitr. Klin. Chir. 3:443-466, 1887.

2. Busch, W. Uber den einfluss welchen heftigere erysipeln suweilen auf organisierte neubildungen ausuben. Verhandl. Naturh. Preuss. Rhein West Phal. 23:28-30, 1866.

3. Pettigrew, R. T., J. M. Galt, C. M. Ludgate, D. B. Horn, and A. N. Smith. Circulatory and biochemical effects of whole body hyperthermia. Br. J. Surg. 61:727-730, 1974.

4. Santamarie, L. J., M. M. Burgess, and D. W. Dery. Physiological effects of water cooling and oxygen ventilation in different space flight conditions. Aerospace Med., Col. 37:300, 1966.

5. Webb, P. Rewarming after diving in cold water. Aerospace Med. 44:1152-1157, 1973.

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| Program Element: | 6.11.01.A IN-HOUSE LABORATORY INDEPENDENT RESEARCH |
| Project: | 3A161101A91C In-House Laboratory Independent Research |
| Work Unit: | 028 Physiologic Correlates of Induced Severe Hyperthermia in Man |
| Study Title: | Predictive Modeling of Hyperthermia |
| Investigators: | Gaither D. Bynum, M.D., MAJ, MC, Kent B. Pandolf, Ph.D. and Ralph F. Goldman, Ph.D. |

Background:

Available biophysical data from copper manikin studies of a system (heated water circulating undergarment, insulating suit and temperature controller) and physiological data from 9 subjects exposed in this system to elevations of deep body temperatures to the $39.2 \pm 0.3^{o}C$ level, were used to develop a prediction model of interaction between the subjects and this heating system. The objective was to develop predicted responses for the various physiological parameters studied, with associated, normal, two-standard deviation variability. These projected responses could then be extrapolated to suggest an anticipated "normal" response, and acceptable deviation, when patients at the National Cancer Institute became subjects for induction of $42^{o}C$ body core temperatures.

Progress:

The linear "curve" of best fit obtained from plotting metabolic rate (MR) vs. rectal temperature ($T_{re}$) is described by the equation MR (Watts) = 11.26 $T_{re}$ ($^{o}C$) - 320. Correlation between MR and $T_{re}$ was r = 0.6966. There was considerable variation in response between subjects and this rise was not statistically significant. Projected time to achieve the $42^{o}C$ levels of core temperature were 3 to 4 hours for all subjects. For the three subjects unable to complete the study, mean heart rate, blood pressure, rate of $T_{re}$ and esophageal temperature ($T_{es}$) rise were not significantly different at comparable temperatures than mean values from those completing the study. At equal temperatures, respiratory rates were

significantly higher ($P<0.05$) for those not completing the study when compared with these subjects completing the study, suggesting the desirability of a means to control the effects of hyperventilation.

These data will be incorporated into a prediction model considering passive human hyperthermia. More importantly, the higher core temperatures measured at the National Institutes of Health on volunteer patients with cancer will be accessible to USARIEM. These data will allow modelling of elevations in core temperature during "rest" to $T_{re} \simeq 42^{o}C$.

Presentations:

None

Publications:

None

Program Element: 6.11.01.A IN-HOUSE LABORATORY INDEPENDENT RESEARCH

Project: 3A161101A91C In-House Laboratory Independent Research

Work Unit: 028 Physiologic Correlates of Induced Severe Hyperthermia in Man

Study Title: Collaboration in Clinical Evaluations of Hyperthermia ($T_{re} \simeq 42^{o}C$) at National Cancer Institute

Investigators: Gaither D. Bynum, M.D., MAJ, MC, Kent B. Pandolf, Ph.D., W. Schuette, Joan Bull, M.D., Ralph F. Goldman, Ph.D.

Background:

Upon completion of the exposures of volunteers to induction of hyperthermia to a $39.2^{o}C \pm 0.3^{o}C$ level using the circulating water suit and controller at USARIEM (16), recommended modifications in the HCA-II controller were performed. The system was then shipped to NCI, Bethesda and studies involving patient exposure were initiated there. USARIEM collaboration continued, with a view toward contributing both our general expertise in hyperthermia and the experience gained in the studies at USARIEM and also to gain otherwise unavailable information on physiologic responses and status of essentially normal (i.e. non-debilitated, despite cancer) individuals with body temperatures of $41.8 \pm 0.2^{o}C$.

Progress:

To date, five cancer patients in otherwise good physiologic status, but for whom other therapy modes had been exhausted, have volunteered for hyperthermic exposure. Ages ranged from 19-56; mean age was 43 yrs. Hyperthermia was induced in each patient on a minimum of two occasions. The first exposure (condition A: $T_{re}$ 39.5 - $40.5^{o}C$) was to familiarize patients with the suit and establish that their responses to thermal stress were comparable to those experienced by the normal population at USARIEM: no sedation was used. During the second exposure (condition B; $T_{re}$ $41.8 \pm 0.2^{o}C$), hyperthermia was induced in these patients as an experimental mode of cancer therapy. Patients were sedated

with Ketamine 25 gm/min/kg, Valium 2.5 gm/min/kg, and Pentothal 25 gm/min/kg, intravenously beginning at $40^{o}C$ $T_{es}$. These doses, though large in comparison to those given to normothermic patients, were necessary to maintain a conscious but sedated state during hyperthermia. Immediately prior to the studies the HCA-II rectal, esophageal, and three skin thermistors were positioned. Esophageal probe position was again documented by X-ray. The patient was clothed in a light cotton garment to prevent contact burns and asked to lie supine in the suit. A 20 gauge intravenous catheter was placed in the external jugular. One quarter strength normal saline, in $D_5W$ with 20 me of KCl was administered at a rate of 1 liter per hour. A 20 gauge radial artery catheter was placed and connected to a Statham pressure transducer to monitor blood pressure (BP). Four electrodes were placed on the chest to monitor EKG and respiratory rate (RR). A plethysmograph was placed on the earlobe to monitor heart rate (HR). Blood pressure, HR, RR, and EKG were displayed on Hewlett Packard 78304A oscilloscopes and 78202B digital displays. Exposure limits were: HR 200, $T_{sk}$ $44^{o}C$. The conscious patients were heated to the preset maximum temperatures and maintained at that temperature for one hour, then cooled by draping with cold, wet towels.

Mean values for BP, HR, RR, $T_{re}$, $T_{es}$ are presented for exposures of normal controls and for NCI patient exposures to $39.0^{o}C$ and $42^{o}C$ in Table 1. For both patient studies, the rate of rise in rectal temperature was $1.8^{o}C/hr$; the rate of rise of esophageal temperature was $2.3^{o}C/hr$. A cooling rate of $6^{o}C/hr$ was accomplished by opening the insulating barrier and draping the patient with cool wet towels. There was no significant difference in the HR, BP, RR, and temperature responses between conditions $T_{es}$ $39.5\text{-}40.5^{o}C$ and $T_{es}$ $41.8 \pm 0.2^{o}C$, with the exception of HR as cooling was begun.

Only two of the five patients heated to $41.8 \pm 0.2^{o}C$ demonstrated enzyme elevations suggestive of tissue damage; an elevation of SGPT in these patients suggested hepatic damage. Elevations of SGOT, CPK, Alk Phos and LDH enzymes, while less specific, suggested possible cellular damage in red blood cells, brain, skeletal or cardiac muscle. The relation of enzyme elevation to heat injury has been discussed in the literature (1). It must be remembered that this study is a part of a larger clinical program designed on the hypothesis that limited, controlled cell

damage can be induced with hyperthermia for therapeutic purposes. These volunteers experienced no lasting, clinical side effects of the hyperthermia procedure. Only two of the five experienced any post-treatment sequelae; both experienced a mild, transient febrile episode.

In the 9 USARIEM subjects, HR and BP responses to induced hyperthermia were similar to those reported in the literature (16). The respiratory rate of the six individuals completing the experiment showed only nominal Q10 effect. The three subjects who did not complete the study demonstrated a Q10 effect with respiratory rates (RR) rising to 28 b/min; though none of these subjects experienced tetany, all demonstrated tingling sensations in the hand and shoulder and were removed from the study. The mean data of the six remaining subjects are therefore biased, having been obtained from individuals less susceptible to hyperventilation. Considering only their data, it is not clear whether this decreased susceptibility is psychological or physiological in origin. However, since the RR of those subjects completing the study was not significantly different from the highly motivated patients at NCI, heated to 39.5-40.0$^{o}$C, we suggest that the variation in RR in the Natick subjects was psychosomatic in origin. A comparison of the responses of the USARIEM subjects with those of the patients at NCI can be made using Figures 1 and 2; aside from the slow onset of body temperature rise at USARIEM (eliminated by a modification of technique before the studies were conducted at NCI) the changes in other physiological parameters between the 39.5$^{o}$C and 42$^{o}$C levels of body temperature are surprisingly minor.

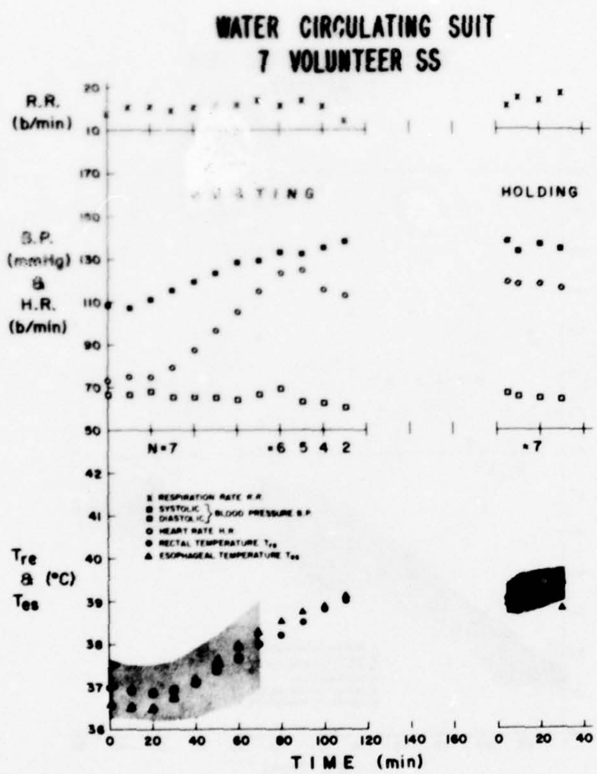


Figure 1. Physiological responses of 7 volunteers, heated to ~ 39.5°C rectal temperature.

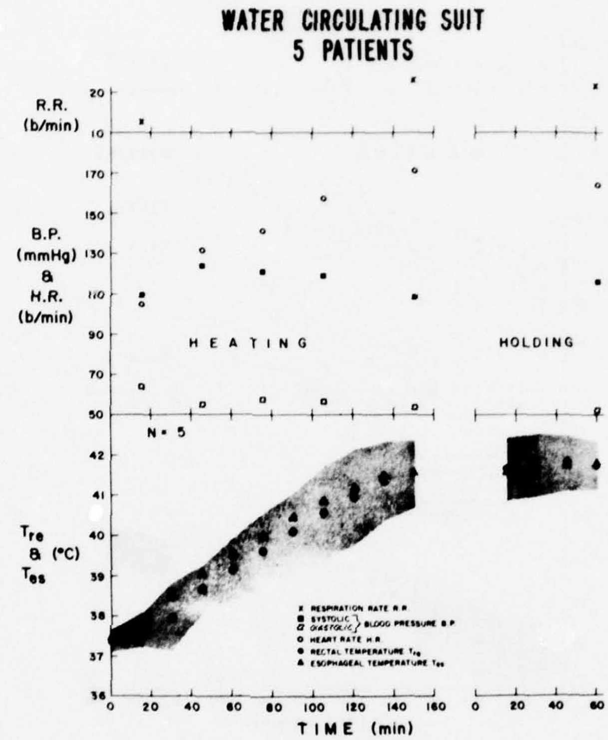


Figure 2. Physiological responses of 5 patients, heated to ~ 42°C rectal temperature.

These data suggest that the "classic" definition of critical thermal maximum (CTM) is restrictive: i.e. a definable temperature range which results in a near lethal or lethal event - heatstroke. When considered with other data in the literature, this data presented support the concept that the CTM is not a unidimensional function of body temperature but rather a multidimensional function involving at least one other variable - time. These data also suggest that a graded subclinical injury response may occur prior to the classic all or none phenomenon of heatstroke and heat collapse.

The classic definition of CTM is not restrictive by intent but rather as a historical by-product. Though heatstroke is one of the oldest of recorded diseases (II Kings 4:18-20), its recognition by northern European culture as a common clinical syndrome did not occur until the eighteenth and nineteenth centuries when large military forces were exposed to warm environments (2). The association between lack of acclimatization, high body temperatures and the clinical and pathologic findings of heatstroke victims did not occur until the nineteenth century (2,3). The use of ice water cooling as a therapy mode also appeared in the literature at that time (4). Since the original conceptual constructs of heat injury were shaped by retrospective analysis and limited by the available technology, the classic definition of CTM appropriately evolved as the relationship between a specific body temperature range and a constellation of near lethal or lethal clinical symptoms. Current estimates of CTM based upon temperature alone, range from 41.5 (5) to 42.0°C (6). Under very select circumstances, or with select individuals, these estimates of CTM based on body temperature alone do not pertain. Our data indicate that sedated, well-hydrated, unacclimatized, resting men can tolerate body temperatures of 41.6-42.0°C. Pettigrew et al. have demonstrated similar findings in patients under general epidural anesthesia (7). Rectal temperatures of 41.8°C have been recorded in marathon runners during competition (8). In these cases no catastrophic clinical events occurred which would warrant defining the temperature range 41.6-41.8°C as a critical thermal maximum.

Good experimental evidence exists which suggests that CTM is a multidimensional function involving at least one other variable - time. Cell culture data suggest that there is exponential relationship between the hyperthermia exposure time required for cell death and temperature. Such data indicates that at 38°C a

low rate of cell thermal injury occurs, while at 56°C the thermal injury rate is such that cell survival time is less than 15 seconds (9,10). Hubbard et al. (11,12) and Shapiro et al. (13) have demonstrated good correlation between mortality and exposure time at high body temperatures in animal models. Wyndham et al. (14) have demonstrated in humans that reducing the time spent at elevated temperatures reduces heatstroke mortality. However, our data indicate that under the experimental conditions described, an exposure to body temperatures of 41.6-42.0°C for one hour did not induce symptomatology suggestive of the near lethal or lethal events classically utilized as criteria for CTM. Pettigrew et al. have maintained patients under general epidural anesthesia for up to 8 hours at body temperatures of 41.6-42.0°C without ill effects (7). This, when combined with the experimental data which indicates the exsitence of heat resistant individuals in a population (15), suggests that these data are useful in defining the time temperature interaction of the human CTM only to the extent that they establish an outer envelope or extreme limit of hyperthermia exposure compatible with uncomplicated recovery of normothermic regulation. It is suggested that CTM be redefined as the particular combination of exposure time at elevated body temperatures which results in either subclinical ($CTM_s$) or clinical ($CTM_c$) injuries.

A mathematical technique, equivalent time at 42°C (ET42), for expressing hyperthermia in terms of body temperature and exposure time has been developed by Schuette at NCI for these cancer studies. He concluded that the relationship between temperature and time is a non-linear function that must be taken into account when assessing the extent of a given hyperthermia treatment for a cancer patient. If time, temperature and lethality data from hyperthermic cell cultures are plotted semi-logarithmically for a constant lethality (50%), an exponential time-temperature relationship becomes apparent. The regression equation is of the form:

$$\text{TIME} = ae^{-bT}$$

Where a and b are constants and T is the temperature of the tumor cell in °C. Time-temperature exposure data may be normalized into equivalent times at 42°C, using a modified regression equation. This equation is determined by solving the original equation for a, using the average rate constant b (from data on cell culture mortality, b = 1.353); with a time increment equal to 1 and a temperature of 42°C,

the value for a obtained is $4.7178 \times 10^{24}$. Temperature records may, accordingly, be normalized to equivalent time at $42^{o}C$ ($T_{eq}$ $42^{o}$) by the summation of the expression:

$$T_{eq}\ 42^{o} = (\Sigma \Delta time/4.7178 \times 10^{24}) \times e^{-1.353T}$$

A similar, or perhaps the identical, relationship may be usefully applied to studies of heat stroke mortality.

Future Plans:

As additional data become available and as more patients are evaluated, additional measurements of cardiovascular parameters will also be performed. The latter will be most instructive in assessing factors contributing to heat exhaustion collapse. While no new data collection will be initiated at USARIEM, collaborative contact with NCI on this project will be continued.

Presentations:

None

Publications:

None

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TABLE

Mean Values of Physiologic Responses in Hot Water Suit:

| | | INITIAL | BEGIN HOLD | BEGIN COOL | END |
|---|---|---|---|---|---|
| | | **6 Normal Ss heated to 39.3 ± 0.2°C (USARIEM)** | | | |
| Time | (min) | 0 | 60 | 135 | 150 |
| $T_{re}$ | (°C) | 36.9 ± 0.2 | 39.1 ± 0 | 39.5 ± 0 | 39.0 ± 0.1 |
| $T_{es}$ | (°C) | 36.5 ± 0.1 | 39.0 ± 0.2 | 38.8 ± 0.1 | 37.7 ± 0.1 |
| HR | (b/m) | 74 ± 2 | 116 ± 4 | 108 ± 4 | 99 ± 6 |
| Syst. | (mmHg) | 112 ± 5 | 138 ± 8 | 130 ± 16 | 121 ± 8 |
| Diast. | (mmHg) | 68 ± 6 | 68 ± 5 | 62 ± 2 | 62 ± 1 |
| Resp. | (b/m) | 13 ± 1 | 15 ± 2 | 18 ± 3 | 13 ± 2 |
| | | **5 Patients heated to 39.0 ± 0.2°C (NCI)** | | | |
| Time | (min) | 0 | 60 | 135 | 150 |
| $T_{re}$ | (°C) | 37.4 ± 0.1 | 40.0 ± 0.3 | 40.0 ± 0.4 | 39.3 ± 0.4 |
| $T_{es}$ | (°C) | 37.2 ± 0.2 | 40.0 ± 0.2 | 40.1 ± 0.2 | 38.4 ± 0.2 |
| HR | (b/m) | 96 ± 13 | 138 ± 12 | 141 ± 12 | 132 ± 12 |
| Syst. | (mmHg) | 123 ± 5 | 141 ± 15 | 138 ± 14 | 118 ± 8 |
| Diast. | (mmHg) | 69 ± 4 | 67 ± 9 | 67 ± 10 | 61 ± 5 |
| Resp. | (b/m) | 15 ± 2 | 21 ± 3 | 23 ± 3 | 22 ± 3 |
| | | **5 Patients heated to 41.8 ± 0.2°C (NCI)** | | | |
| Time | (min) | 0 | 150 | 210 | 245 |
| $T_{re}$ | (°C) | 37.3 ± 0.1 | 41.4 ± 0.1 | 41.2 ± 0.1 | 39.1 ± 0.4 |
| $T_{es}$ | (°C) | 37.1 ± 0.1 | 41.5 ± 0.1 | 41.6 ± 0.1 | 38.0 ± 0.3 |
| HR | (b/m) | 96 ± 8 | 154 ± 15 | 163 ± 17 | 134 ± 17 |
| Syst. | (mmHg) | 119 ± 5 | 114 ± 11 | 121 ± 13 | 109 ± 8 |
| Diast. | (mmHg) | 66 ± 5 | 58 ± 9 | 57 ± 7 | 64 ± 6 |
| Resp. | (b/m) | 13 ± 1 | 23 ± 3 | 21 ± 1 | 16 ± 1 |

(82001)

| RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY | 1. AGENCY ACCESSION* | 2. DATE OF SUMMARY* | REPORT CONTROL SYMBOL |
|---|---|---|---|
| | DA OA 6142 | 77 10 01 | DD-DR&E(AR)636 |

| 3. DATE PREV SUM'RY | 4. KIND OF SUMMARY | 5. SUMMARY SCTY* | 6. WORK SECURITY* | 7. REGRADING* | 8a. DISB'N INSTR'N | 8b. SPECIFIC DATA-CONTRACTOR ACCESS | 9. LEVEL OF SUM |
|---|---|---|---|---|---|---|---|
| 77 06 15 | D. Change | U | U | NA | NL | ☒ YES ☐ NO | A. WORK UNIT |

| 10. NO./CODES:* | PROGRAM ELEMENT | PROJECT NUMBER | TASK AREA NUMBER | WORK UNIT NUMBER |
|---|---|---|---|---|
| a. PRIMARY | 6.11.02.A | 3E161102BS08 | 00 | 001 |
| b. CONTRIBUTING | | | | |
| c. XXXXXXXX | CARDS 114f | | | |

11. TITLE (Precede with Security Classification Code)* (U)Development of Cold Models and Characterization of Frostbite, Non-Freezing Cold Injuries and Whole Body Heat Loss Common to the Soldier(22)

12. SCIENTIFIC AND TECHNOLOGICAL AREAS* 002300 Biochemistry;005900 Environmental Biology;012900 Physiology;003500 Clinical Medicine

| 13. START DATE | 14. ESTIMATED COMPLETION DATE | 15. FUNDING AGENCY | 16. PERFORMANCE METHOD |
|---|---|---|---|
| 70 07 | CONT | DA | C. In-House |

17. CONTRACT/GRANT

a. DATES/EFFECTIVE: EXPIRATION:

b. NUMBER:* NOT APPLICABLE

c. TYPE: d. AMOUNT:

e. KIND OF AWARD: f. CUM. AMT.

| 18. RESOURCES ESTIMATE | | a. PROFESSIONAL MAN YRS | b. FUNDS (In thousands) |
|---|---|---|---|
| FISCAL YEAR | PRECEDING 77 | 2.4 | 100 |
| | CURRENT 78 | 1.4 | 52.9 |

19. RESPONSIBLE DOD ORGANIZATION

NAME:* USA RSCH INST OF ENV MED

ADDRESS:* Natick, MA 01760

RESPONSIBLE INDIVIDUAL

NAME: DANGERFIELD, HARRY G., M.D., COL, MC

TELEPHONE: 955-2811

20. PERFORMING ORGANIZATION

NAME:* USA RSCH INST OF ENV MED

ADDRESS:* Natick, MA 01760

JACKSON, Ronald E., MAJ, MC

PRINCIPAL INVESTIGATOR (Furnish SSAN if U.S. Academic Institution)

NAME:* DENNISTON,Joseph C.,VMD,Ph.D.,MAJ,VC

TELEPHONE: 955-2813

SOCIAL SECURITY ACCOUNT NUMBER:

ASSOCIATE INVESTIGATORS

NAME: HAMLET, Murray P., D.V.M.

NAME: 955-2865 DA

21. GENERAL USE

Foreign Intelligence Not Considered

22. KEYWORDS (Precede EACH with Security Classification Code) (U)Cold Injury; (U) Frostbite; (U) Thermoregulation; (U) Microwave Radiometer; (U) Osteocytes; (U) Cryobiology; (U) Fasciotomy

23. TECHNICAL OBJECTIVE,* 24. APPROACH, 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)

23. (U)Study factors involved in frostbite and other non-freezing injuries in both animals and man. Provide a rational basis for treatment and prevention of those injuries sustained by military operations.

24. (U)Attempts to produce radiographic bone changes seen in recooperation of frostbite victims will be included in an animal model. Mild frostbite lesions will be produced and sequential radiographs taken to identify the production of the radiographic changes. The ability to measure temperature from deep within the tissue would be advantageous in the clinical evaluation of frostbite lesion. Attempts to utilize the microwave radiometer on an animal model will progress this quarter.

25. (U)76 10 - 77 09 Studies with fasciotomy have demonstrated a significant prolongation of integrity of the local vascular system and fasciotomy resulted in total foot salvage in several dogs. Preliminary studies with the microwave radiometer for blood flow measurements would indicate that the tissue compression necessary for proper flow measurements compromise accurate measurements. Preliminary data on the evaluation of human finger cooling in air have been attained and further data collection and analysis will continue for characterization of human finger cooling.

*Available to contractors upon originator's approval.

Program Element: 6.11.02.A DEFENSE RESEARCH SCIENCES, ARMY

Project: 3E161102BS08 Environmental Stress, Physical Fitness and Medical Factors in Military Performance

Work Unit: 001 Development of Cold Models and Characterization of Frostbite, Non-Freezing Cold Injuries and Whole Body Heat Loss Common to the Soldier

Study Title: Characteristics of Human Finger Cooling in Air at $0^{o}C$

Investigators: James J. Jaeger, CPT, MSC, James B. Sampson, Ph.D., Donald E. Roberts, Ph.D., and James E. McCarroll, MAJ, MSC

Background:

One of the missions of the Cold Research Division is to devise and evaluate measures which will enable an individual to prevent or delay the onset of cold injury. Since frostbite of the extremities, particularly the hands, is a common cold injury, it would be advantageous to have a model upon which the efficacy of various prophylactic interventions could be tested.

The literature on human peripheral circulation in the cold is quite extensive (1). However, only a few studies have attempted to examine the inter- and intra-individual variability of the hand temperature response to local cooling. Teichner (3) has observed large variations among individuals in the latency of cold-induced vasodilation (CIVD) and other parameters of the cooling hand in water. He reports that a large number of individuals fail to show CIVD at all. He classified individuals into slow, medium, and fast vasodilators and suggested the differences were a result of differences in arousal levels. Yoshimura and Iida (4,5) and Yoshimura et al. (6) have identified a number of sources of variation in the cooling pattern of a single finger immersed in ice water. These include age, sex, nationality, race, prior cold exposure, autonomic tone, and diet. All the studies cited above have used cold water to achieve hand and finger cooling. To the best of our knowledge, there is no comparable data on hands and fingers exposed to cold air. Since an air exposure has certain advantages over water immersion for the types of studies planned by the Cold Research Division, it was necessary to evaluate human hand cooling curves in terms of various time and temperature characteristics and to determine inter- and intra-subject variability.

Progress:

Because data should come from a large number of test subjects with as little experimental intervention as possible, it is anticipated that 50 test subjects will be needed. The data reported here represent information obtained from 14 subjects who have completed the full set of exposures to date. Subjects in groups of seven were seated around a large table in a cold chamber which was maintained at $0 \pm 1^{o}C$. Wind speed was approximately 0.15 meters per second. Subjects wore a standard military arctic uniform. Previous experimentation with this clothing ensemble has shown that there is no significant change in mean weighted skin temperature, rectal temperature or heart rate during a two-hour exposure to $0^{o}C$ air. Subjects sat with their arms supported at heart level by a nylon mesh net which allowed free circulation of air around the hands. After 15 minutes in the chamber, the right hand glove was removed from all subjects. For the next 120 minutes the skin temperature of the thumb, middle finger and small finger was measured once a minute by a 30 gauge thermocouple placed 5 mm behind the nail bed.

Each subject was tested on seven separate occasions within a three-week period. The first week subjects were tested at the same time of day, Monday thru Friday. They were then retested on the following two Tuesdays.

Figure 1 illustrates the middle finger skin temperature response of three subjects. This plot indicates the range of finger temperature responses encountered. All three subjects showed an initial period of cooling immediately following removal of the glove at 15 minutes. Some subjects' fingers cooled very little beyond an initial 5 to $8^{o}C$ drop as seen for Subject 16. Most subjects demonstrated the pattern shown for Subject 10, which consists of a slow cooling phase followed by one or more episodes of skin warming. These events are the well known Lewis waves (2) otherwise known as cold induced vasodilation (CIVD). A CIVD event was arbitrarily defined as a rise in skin temperature of at least $2^{o}C$ which was sustained for two minutes or more. At the other extreme a few subjects' fingers cooled continuously as illustrated by the plot for Subject 4. The temperature record for Subject 4 ends at 50 minutes because the temperature of his small finger had fallen to $4.5^{o}C$. Subjects were removed from the cold chamber

when any skin temperature reached this level. Although these three plots show the range of responses they do not convey the magnitude of the problem of between subject variability.

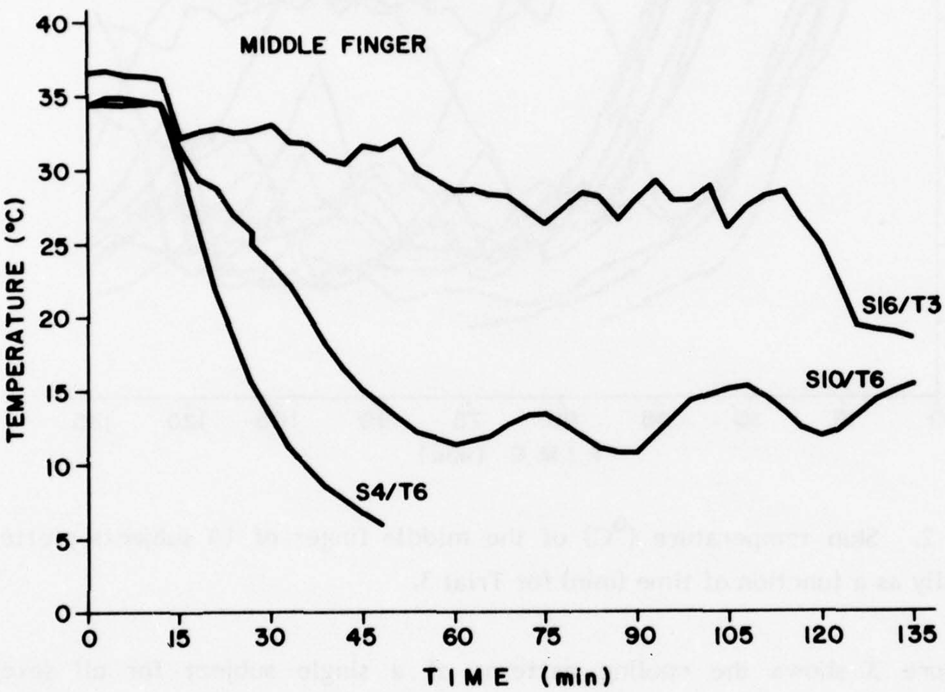


FIGURE 1. Skin temperature ($^{o}$C) of the middle finger of three subjects versus time (min). "S" refers to subject number and "T" refers to trial number.

Figure 2 illustrates the cooling patterns of all 14 subjects for a single exposure plotted in the same axis. It is immediately obvious that between subject variability was considerable and must be dealt with in the design of the study. Fortunately, the within subject variability of cooling patterns was markedly less.

...program designed on the hypothesis that limited, controlled cell

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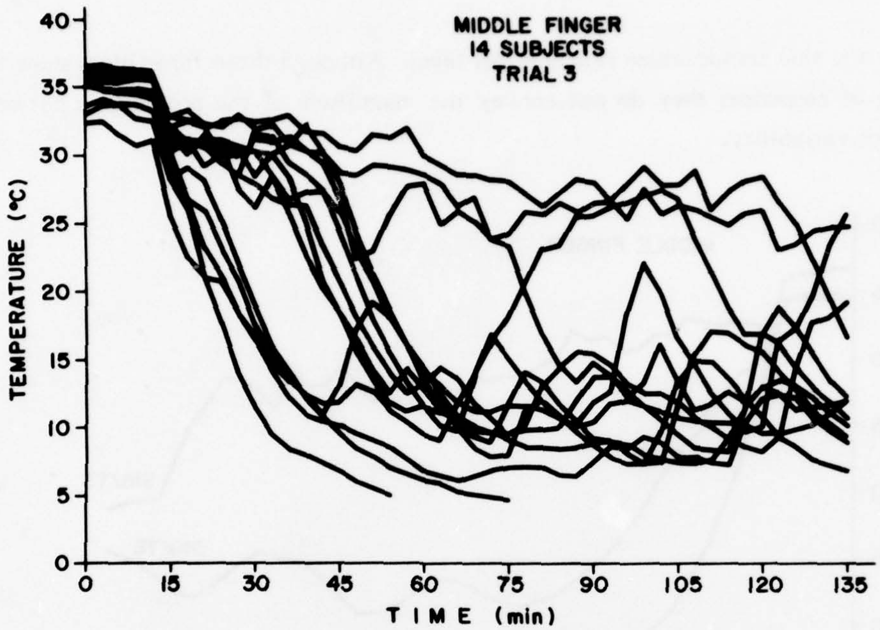


FIGURE 2. Skin temperature ($^{O}$C) of the middle finger of 14 subjects plotted individually as a function of time (min) for Trial 3.

Figure 3 shows the cooling patterns of a single subject for all seven exposures. The day to day variations in cooling patterns for the other 13 subjects were similar in magnitude. Of the seven cooling patterns shown in Figure 3, one illustrates an unusually large CIVD event. This large warming episode represents an extreme in the amplitude of CIVD events observed. The amplitudes of CIVD events varied between the minimum 2$^{O}$C rise and the 20$^{O}$C rise depicted in Figure 3. The amplitude and/or duration of CIVD events were not characteristic of individuals, fingers, or trials.

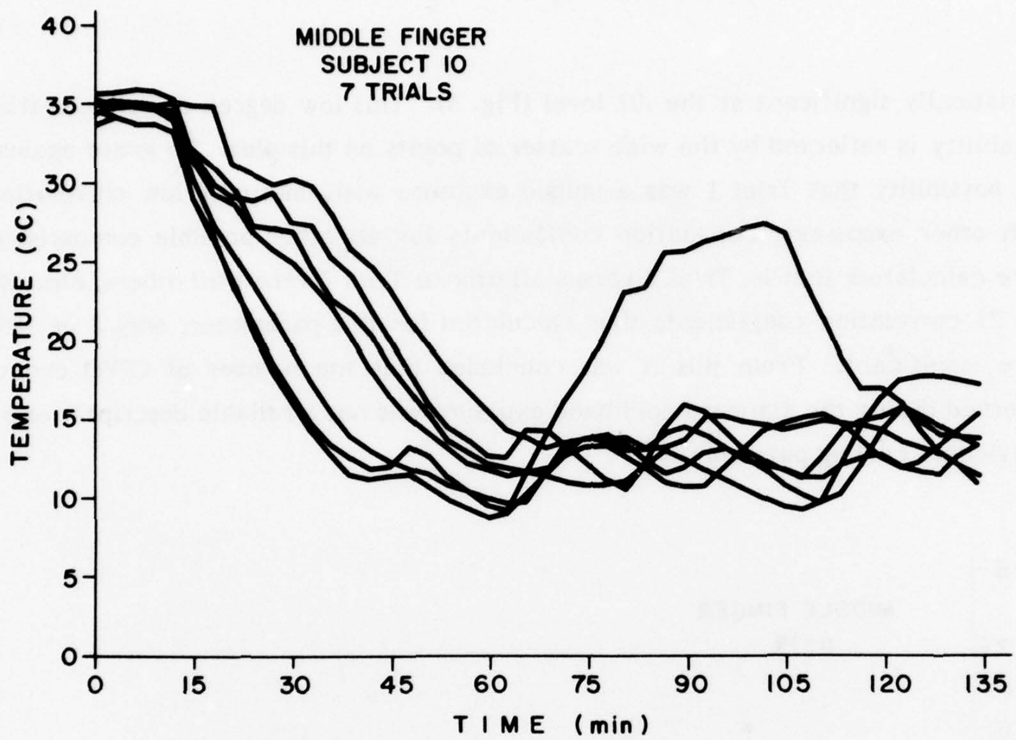


FIGURE 3. Skin temperature ($^{O}C$) of the middle finger of Subject 10 for seven trials plotted individually as a function of time (min).

In the past, various indices derived from skin temperature measurements have been used to characterize the entire finger cooling process (3,4). This is a useful approach since it allows for simple statistical comparison of a large number of these cooling curves. To the best of our knowledge, however, there has not been a systematic evaluation of these indices to test their reproducibility over time in the absence of experimental treatments.

In Figures 4, 5, 6, and 8, the more common descriptors of finger cooling are depicted in terms of their correlation between trials. In these figures, a particular parameter for the first trial is represented on the X axis while the same parameter as measured in the other six exposures is represented on the Y axis. To help visualize the trial by trial correlations a line of best fit was drawn for each of the six comparisons.

For the number of CIVD events for the middle finger, only three of the six correlation coefficients calculated for Trial 1 versus the other six trials were

statistically significant at the .01 level (Fig. 4). This low degree of between trial reliability is reflected by the wide scatter of points on this plot. To guard against the possibility that Trial 1 was a unique exposure with unusually low correlation with other exposures, correlation coefficients for all other possible comparisons were calculated; that is, Trial 2 versus all others; Trial 3 versus all others, etc. Of the 21 correlation coefficients thus calculated for this parameter, only 8 or 38% were significant. From this it was concluded that the number of CIVD events observed during the standard cold hand exposure was not a reliable descriptor of an individual's cooling pattern.

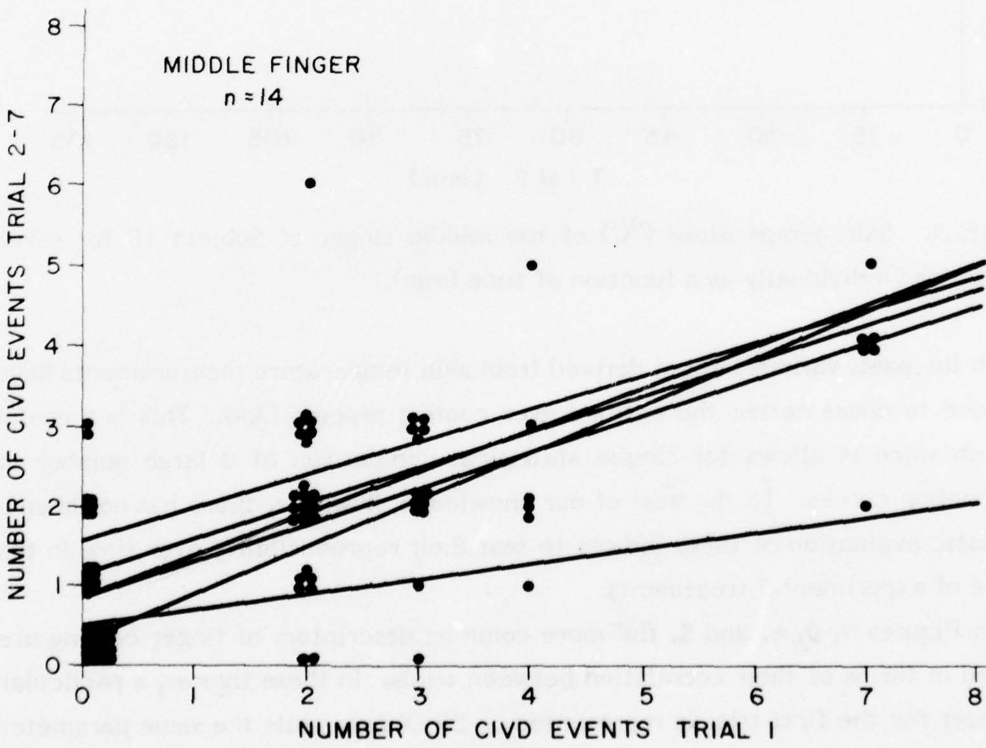


FIGURE 4. Number of CIVD events in Trials 2 thru 7 as a function of the number of CIVD events in Tone. 1. n = 14. Lines of best fit are shown for each of the six trial by trial comparisons.

Two other parameters which have been used in the literature as descriptors of finger cooling are the temeprature and the time at which the first CIVD event occurs after the start of a cold exposure. The plot shown in Figure 5 is that for time of the first CIVD event but the situation it depicts is the same as that for the temperature of the first CIVD event. Again, only the Trial 1 versus Trial 2 thru 7 comparisons are depicted in this plot. The wide scatter of points on this plot illustrates the fact that there was not a single significant correlation coefficient among all possible trial by trial comparisons. From the data presented so far it is obvious that any attempt to categorize individuals or test the effects of treatments on finger cooling by measuring aspects of CIVD activity is very difficult due to the high variability of CIVD events. A far more reliable parameter to describe the cooling process is simply mean temeprature.

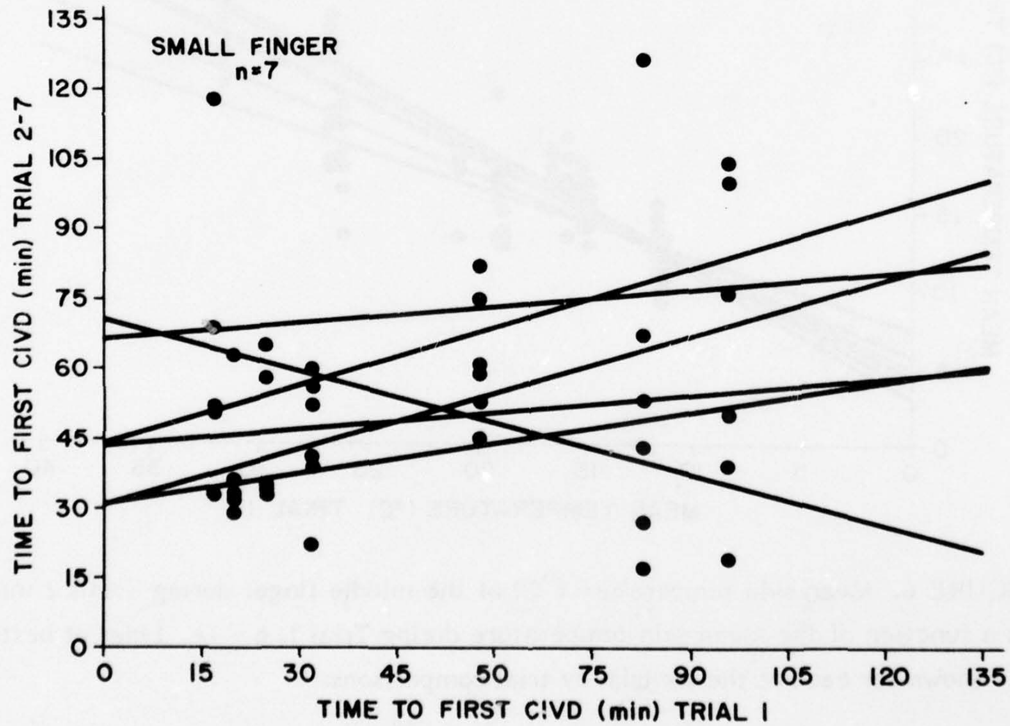


FIGURE 5. Time (min) to the first CIVD event in Trials 2 thru 7 as a function of the time to the first CIVD event in Trial 1. n = 7. Lines of best fit are shown for each of the six trial by trial comparisons.

Figure 6 is the plot of the Trial 1 versus Trial 2 thru 7 values for mean temperature of the middle finger. All six correlation coefficients were significant at the .01 level. In fact, all 21 of the possible trial by trial correlation coefficients were significant. Although not especially elegant, the simple calculation of mean skin temperature during the exposure period appeared to be a reliable method of describing the finger cooling process.

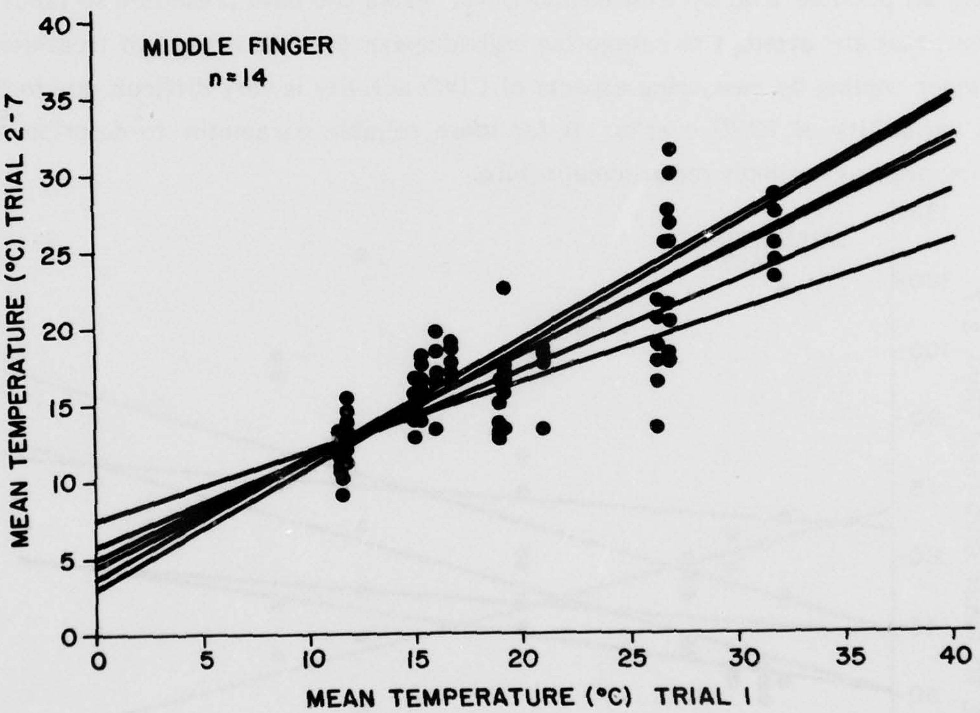


FIGURE 6. Mean skin temperature ($^{o}$C) of the middle finger during Trials 2 thru 7 as a function of the mean skin temperature during Trial 1. n = 14. Lines of best fit are shown for each of the six trial by trial comparisons.

However, for the experimental design used, calculation of mean temperature can lead to a misinterpretation of the data. Since the cold exposure of an individual was terminated when any skin temperature reached 4.5$^{o}$C, not all subjects completed the two hour exposure.

To illustrate the problem, Figure 7 shows the finger temperature response during Trial 3 for Subjects 3 and 4. Their mean finger temperatures were 12.5°C and 12.1°C respectively. On this basis there is little to differentiate between the two subjects although it is obvious that their cooling patterns are quite different. To account for the varying exposure times the procedure of calculating the area under the temperature versus time curve was adopted. For this example the resulting areas were approximately 2100 degree minutes for Subject 3 and 800 degree minutes for Subject 4. The 2.6 fold difference between these values enabled their cooling patterns to be categorized.

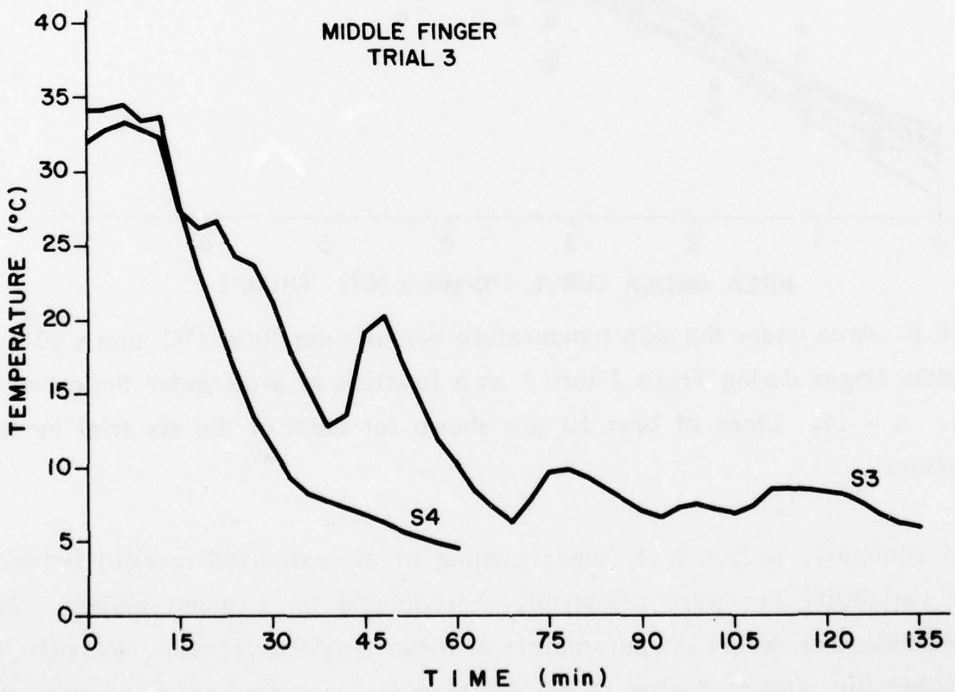


FIGURE 7. Skin temperature (°C) of the middle finger of two subjects versus time (min) for Trial 3. "S" refers to subject number.

When subjected to the same correlation analysis as the other parameters, the measurement of area under the cooling curve showed very good between-trial correlation with 100% of all possible trial by trial correlation coefficients being significant at the .01 level (Figure 8). This high degree of between-trial reliability also held for the thumb and small finger.

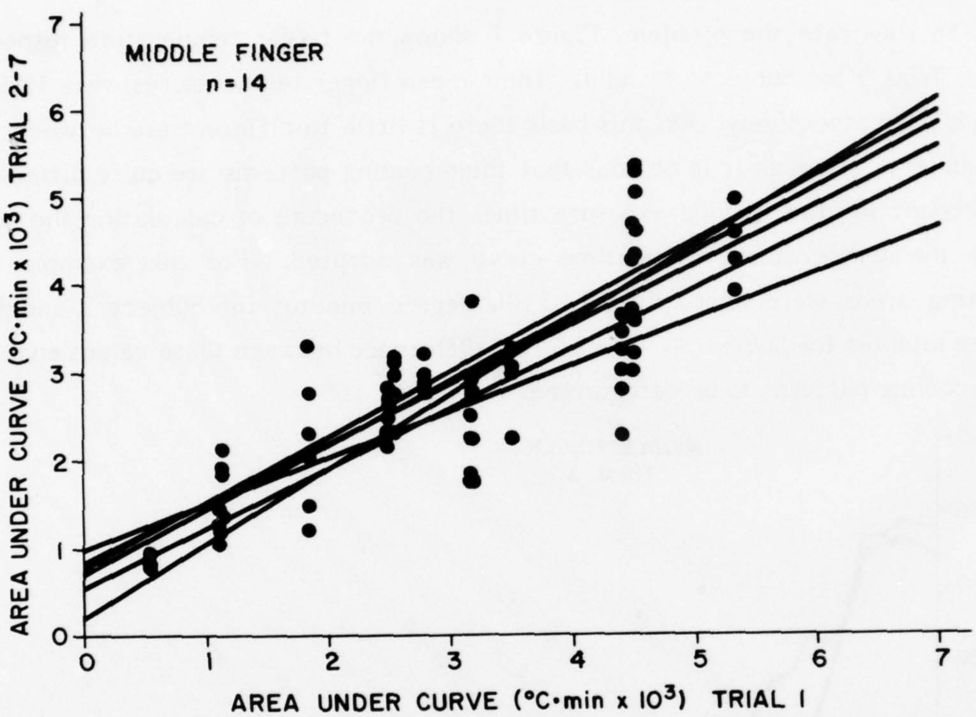


FIGURE 8. Area under the skin temperature versus time curve ($^{o}C$ min x $10^{3}$) for the middle finger during Trials 2 thru 7 as a function of area under the curve for Trial 1. n = 14. Lines of best fit are shown for each of the six trial by trial comparisons.

In summary, patterns of finger cooling in air exhibited marked between-subject variability but were reasonably reproducible for a given subject. In a repeated measures design the parameters of mean temperature and area under the curve offer the highest degree of reliability when compared to parameters that describe various aspects of CIVD events. When the exposure times of subjects are not equal the measurement of the areas under the cooling curve allows discrimination between cooling patterns in cases where the measurement of mean temperature can not.

Presentations:

Jaeger, J. J. , J. B. Sampson, D. E. Roberts and J. E. McCarroll. Characteristics of Human Finger Cooling in Air at o$^{o}$C. The Physiologist 20;47, 1977.

Publications:

None

LITERATURE CITED


1. Itoh, S. Physiology of cold adapted man. Sapporo, Japan: Hokkaido University School of Medicine, 1974.

2. Lewis, T. Observations upon the reactions of the vessels of the human skin to cold. Heart 15:177-208, 1930.

3. Teicher, W. H. Individual Thermal and Behavioral Factors in Cold-Induced Vasodilatation. Psychophysiology 2:295-304, 1966.

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6. Yoshimura, H., I. Iida, and H. Kioshi. Studies on the reactivity of skin vessels to extreme cold. Part III. Effects of diets on the reactivity of skin vessels to cold. Jap. J. Physiol. 2:310-315, 1952.

| | |
|---|---|
| Program Element: | 6.11.02.A DEFENSE RESEARCH SCIENCES, ARMY |
| Project: | 3E161102BS08 Environmental Stress, Physical Fitness and Medical Factors in Military Performance |
| Work Unit: | 001 Development of cold models and characterization of frostbite, non-freezing cold injuries and whole body heat loss common to the soldier |
| Study Title: | Preliminary Investigation of Microwave Radiometry in Dog Animal Model |
| Investigators: | Joel J. Berberich, CPT, MSC, Ph.D. and Danney L. Wolfe, CPT, VC, D.V.M. |

Background:

Historically frostbite has been a disorder of military significance. For example, the incidence of frostbite in the Korean conflict was greater than the more widely publicized incidence of malaria in the Viet Nam conflict.

The impact of frostbite has been compounded by the duration of hospitalization, routinely six weeks. This extended hospitalization has been due in part (a) to the lack of measures of the degree and anatomical limit of injury, and (b) to the lack of measures of response to therapy. Thus, any advance to improve these measures for frostbite would be desirable.

A microwave radiometer might be such an advance. The principle of operation of a microwave radiometer is similar to other instruments which measure energy radiated in the visible or infrared bands. However, due to the diminished attenuation of microwaves in tissue, subsurface radiation, and hence temperature theoretically can also be measured.

Microwave radiometry has been employed to measure subsurface temperatures, an indirect measure of blood flow (1). One such operational instrument has been developed by Ronald Porter of Radiometric Technology, Inc., Wakefield, MA. This development has been funded by NASA and by the National Cancer Institute. To date the results with this radiometer, although promising, have been equivocal.

The object of this pilot study was to evaluate the utility of the NASA microwave radiometer for measuring subsurface temperatures as an index of blood

flow for frostbite injury prognosis.

Progress:

We sought to determine whether or not the microwave radiometer could detect step changes in blood flow in the hind limb of a dog animal model. Four mongrel dogs were anesthetized with sodium pentobarbital administered intravenously and blood flow to their hind limb was measured with an electromagnetic flow probe. Surface and deep limb temperatures were measured by needle thermistors and thermocouples. Simultaneously subsurface temperature was measured using the microwave radiometer. Blood flow to the hind limb was altered by occlusion and by short periods of surface cooling, with the intent of comparing changes detected by the microwave radiometer to those detected by the flow probe and temperature sensors.

The microwave radiometer requires firm skin contact to detect subsurface temperatures. It was observed that the resultant tissue compression compromised accurate blood flow measurement in the four experimental animals.

Analysis of the microwave radiometer data have proceeded with difficulty. The data were to have been analyzed by the developer (Radiometric Technology, Inc.) due to the complexity of data reduction. However, this firm ceased business operations before the data could be reduced to a manageable form for analysis. The resources required for data analysis by the USARIEM Information Sciences Branch are not available at the present time.

Presentations:

None

Publications:

None

## LITERATURE CITED

1. Evans, W. O. Personal communication, 1977.

2. Porter, Ronald A. Microwave radiometric detection of subsurface temperatures and fluids in the human body. Summary report. Wakefield, MA: Radiometric Technology, Inc., 42 p., 1974.

Program Element: 6.11.02.A DEFENSE RESEARCH SCIENCES, ARMY

Project: 3E161102BS08 Environmental Stress, Physical Fitness and Medical Factors in Military Performance

Work Unit: 001 Development of Cold Models and Characterization of Frostbite, Non-freezing Cold Injuries and Whole Body Heat Loss Common to the Soldier

Study Title: Orthopedic Changes Following Frostbite in the Cat

Investigators: Murray P. Hamlet, D.V.M.. and David R. Franz, CPT, VC, D.V.M.

## Background:

A small number of references in the literature describe bone changes following frostbite (1,2). The pathological findings are generally classified into several groups by time of appearance following injury, and apparent radiographic changes. Usual classification includes: 1) osteoporosis (most common abnormality reported), 2) acromutilation (seen in individuals sustaining deep injury with tissue loss, 3) juxta-articular areas of decreased density (seen in individuals sustaining 1st and 2nd degree injury, and first noted eight months post injury, and 4) other bone changes, i.e., periostitis, new bone formation, osteomyelitis. The juxta-articular changes are of interest as they resemble the boney erosions and subchondral cysts seen in the later stages of rheumatoid arthritis. Reproduction of the above described injuries in laboratory animals has met with little or no success (3). Successful modeling of cold induced bone lesions would be useful in understanding the tissue response to cold and possibly lead to the production of a model for rheumatoid arthritis as well.

## Progress:

Superficial (1st and 2nd degree) frostbite was produced by immersion in a cooled ethylene glycol bath of one hind foot of three anesthetized domestic felines. Injury was followed radiographically at monthly intervals for 12-16 months. A

diffuse osteoporosis was noted in the digits of the injured extremities at 3-5 months post injury, and was apparent radiographically until the animals were sacrificed at 12 to 16 months post injury. Light microscopy indicated a marked loss of osteocytes per unit area of osteone, illustrating possible vasospasm or occlusion of small distal arterioles from which osteocytes ultimately receive nutrients and oxygen supply. Osteocytes nearest haversion blood vessels, periosteal bone, and articular cartilage were spared, as larger blood vessels remained patent.

The above described pilot work will be expanded and pursued as a part of Dr. Franz research program for his Ph.D. dissertation. Several more pilot animals will be studied beginning in Oct 77. Emphasis will be placed on consistant reproduction of injury and lesions, improvement of technique, i.e., steriotactic positioning of extremities during radiography. Measurement of biochemical indicators of ongoing pathology, i.e., tissue enzymes, rheumatoid factors, etc., is also planned.

Presentations:

None.

Publications:

None.

## LITERATURE CITED

1. Vinson, H. A., R. Schatzki, and K. D. Orr. Roentgenological bone changes encountered in frostbite in Korea 1950-51. Army Medical Branch Lab., Ft. Knox, Kentucky, 1953.

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Program Element: 6.11.02A DEFENSE RESEARCH SCIENCES, ARMY

Project: 3E161102BS08 Environmental Stress, Physical Fitness and Medical Factors in Military Performance

Work Unit: 001 Development of Cold Injury Models and Characterization of Frostbite, Non-Freezing Cold Injuries and Whole Body Heat Loss Common to the Soldier

Study Title: Development of an In Vitro Endothelial Cell Model as It Applies to Cold Induced Ultrastructural Changes.

Investigators: Lynn R. Trusal, CPT, MSC, Ph.D. and Murray P. Hamlet, D.V.M.

## Background:

The importance of an intact vascular system to tissue survival following frostbite injury has been clearly demonstrated (1,3). It is further known that the endothelial cells lining this vascular system are not thrombogenic unless the cells are disrupted. Damage to these cells by freezing can result in initiation of clotting mechanisms, eventual hemostasis, edema and possible necrosis (2). Thus, the fate of the endothelial cells appears to be important in the eventual prognosis following frostbite.

This research project concerns the development of an *in vitro* tissue culture model to study cold induced ultrastructural changes in endothelial cells. The goal is to determine the tolerance of endothelial cells for hypothermic and freezing temperatures with the ultimate aim of preventing the onset of hemostasis and possible loss of limbs. Cellular tolerance will be determined by development of an index of cellular damage as it relates to both temperature and length of exposure which will later be correlated with an *in vivo* animal frostbite model.

## Progress:

In order to develop an *in vitro* tissue culture model to study the events leading to hemostasis following frostbite, we have utilized several sources of

endothelial cells. Both calf aortas and human umbilical veins have been used successfully as sources for these cells. Basically, cells are obtained by collagenase perfusion of the blood vessel and plated in vitro utilizing a complete tissue culture media containing 20% fetal calf serum and antibiotics. To facilitate cellular exposure to environmental extremes and subsequent processing, the use of coverslip cultures has proved successful. Cells grown on either glass or plastic coverslips can be frozen easily and processed for various types of microscopy.

Damage assessment can then be carried out using light microscopy, phase contrast microscopy, scanning electron microscopy and transmission electron microscopy. Preliminary evidence also indicates that release of cellular enzymes may also be used to assess freeze induced damage to endothelial cells.

So that correlations can be drawn to endothelial cells in vivo the cultured cells are grown in confluent, non-mitotic monolayers and processed in this manner through open embedding for electron microscopy. This method is preferable to removing the cells from the coverslip and treating them as a tissue block which causes increased cellular damage and morphological distortion. The use of human endothelial cells will also increase the in vitro to in vivo validity.

To date two sources of endothelial cells on substrates suitable for cold exposure and subsequent examination by several forms of microscopy have been cultured sucessfully and the ability to assess cellular structural damage by means of histological staining, microscopy and enzyme and ion determinations is in progress. Once techniques for the in vitro model system have been perfected, the correlation between cellular damage and the temperature and duration of exposure will be initiated.

It is also planned to later develop a suitable in vivo animal model for validation of the in vitro tissue culture system. Both systems will allow the study of not only cellular damage caused by frostbite or perhaps prolonged hypothermia but the in vitro model has the advantage of long term more highly controlled studies.

Next, the action of chemicals such as acety salicylic acid and a-tocopherol will be evaluated for their ability to prevent or interfere with hemostasis. It may also be a possibility that a-tocopherol by combining with cellular membranes may increase their resistance to freeze damage.

It is hoped, that such studies will increase our knowledge of the pathogenesis of frostbite and lead to ways to prevent hemostasis and loss of limbs.

<u>Presentations:</u>

None.

<u>Publications:</u>

None.

## LITERATURE CITED


1. Kreyberg, L. La stase et san role dans le development de necros. Acta. Pathology Microbiology Scand. Suppl. 91:40-50, 1950.

2. Rabb, J. M., M. L. Renaud, P. A. Brandt and C. W. Witt. Effect of freezing and thawing on the microcirculation and capillary endothelium of the hamster cheek pouch. Cryobiology 11:508-518, 1974.

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(82002)

| RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY | | | | 1. AGENCY ACCESSION* | 2. DATE OF SUMMARY* | REPORT CONTROL SYMBOL |
|---|---|---|---|---|---|---|
| | | | | DA 0A 6144 | 77 10 01 | DD-DR&E(AR)636 |

| 3. DATE PREV SUM'RY | 4. KIND OF SUMMARY | 5. SUMMARY SCTY* | 6. WORK SECURITY* | 7. REGRADING* | 8a. DISB'N INSTR'N | 8b. SPECIFIC DATA-CONTRACTOR ACCESS | 9. LEVEL OF SUM |
|---|---|---|---|---|---|---|---|
| 77 09 02 | D. Change | U | U | N/A | N/L | ☒ YES ☐ NO | A. WORK UNIT |

| 10. NO./CODES:* | PROGRAM ELEMENT | PROJECT NUMBER | TASK AREA NUMBER | WORK UNIT NUMBER |
|---|---|---|---|---|
| a. PRIMARY | 6.11.02.A | 3E161102BS08 | 00 | 002 |
| b. CONTRIBUTING | | | | |
| XXXXXXXXXX | CARDS 114f | | | |

11. TITLE (Precede with Security Classification Code)* (U) Development and characterization of models to study acute mountain sickness and high altitude pulmonary edema in military operations (22)

12. SCIENTIFIC AND TECHNOLOGICAL AREAS*
013400 Psychology; 012900 Physiology; 005900 Environmental Biology

| 13. START DATE | 14. ESTIMATED COMPLETION DATE | 15. FUNDING AGENCY | 16. PERFORMANCE METHOD |
|---|---|---|---|
| 70 07 | CONT | DA | In-House |

17. CONTRACT/GRANT
a. DATES/EFFECTIVE: EXPIRATION:
b. NUMBER:* NOT APPLICABLE
c. TYPE: d. AMOUNT:
e. KIND OF AWARD: f. CUM. AMT.

| 18. RESOURCES ESTIMATE | | a. PROFESSIONAL MAN YRS | b. FUNDS (In thousands) |
|---|---|---|---|
| FISCAL YEAR | PRECEDING 77 | 6.8 | 146 |
| | CURRENT 78 | 3. | 139.2 |

19. RESPONSIBLE DOD ORGANIZATION
NAME:* USA RSCH INST OF ENV MED
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TELEPHONE: 955-2811

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ADDRESS:* Natick, MA 01760
PRINCIPAL INVESTIGATOR (Furnish SSAN if U.S. Academic Institution)
NAME:* MAHER, John T., Ph.D.
TELEPHONE: 955-2851
SOCIAL SECURITY ACCOUNT NUMBER:
ASSOCIATE INVESTIGATORS
NAME: CYMERMAN, Allen, Ph.D.
NAME: 955-2885 DA

21. GENERAL USE
Foreign Intelligence Not Considered

22. KEYWORDS (Precede EACH with Security Classification Code) (U)High Altitude Pulmonary Edema;(U)Acute Mountain Sickness;(U)Organ Wet/Dry Weight Ratios;(U)Fluid Compartments(U)Hematological Changes in the Rat

23. TECHNICAL OBJECTIVE,* 24. APPROACH, 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)

23. (U) Acute mountain sickness and high altitude pulmonary edema are debilitating disorders associated with the lowered oxygen present at high terrestrial elevations. Many of the physiological and biochemical parameters of these disorders cannot be studied in man due to the invasive nature of the measurements. The purpose of this work unit is to develop appropriate animal models allowing for the elucidation of the physiological and biochemical adaptations which occur in response to the stress of high terrestrial elevations.

24. (U) Models will be developed and/or used for investigating physiological and biochemical responses to altitude; (2) control mechanisms operative in these responses; (3) etiology and symptomatology of acute mountain sickness and high altitude pulmonary edema; (4) related functional deficits and disabilities; and (5) factors affecting recovery in order to identify new approaches for improving military effectiveness at high terrestrial elevations.

25. (U) 76 10 - 77 09 Using the laboratory rat as the model animal system, the first phase of a study investigating altitude-induced changes in body fluid compartments was completed. Confirmation of the previously reported shift of plasma from the intravascular compartment was obtained with acute exposure of the rat to high altitude. Hematocrit and hemoglobin concentration increased 9 and 14%, respectively, within 48 hrs. Increases in red blood cell volume are indicative of the movement of fluid into the cellular compartment. Different tissues varied in their sensitivity to this fluid shift. Brain and lung tissue exhibited a 2-fold increase in wet-dry weight ratios. Temporal changes in these ratios also indicated that maximum alterations occur within 48 hrs, a time frame similar to that observed for altitude-related illnesses.

*Available to contractors upon originator's approval.

AD-A060 886 ARMY RESEARCH INST OF ENVIRONMENTAL MEDICINE NATICK MASS F/G 6/5
ANNUAL PROGRESS REPORT, FISCAL YEAR 1977.(U)
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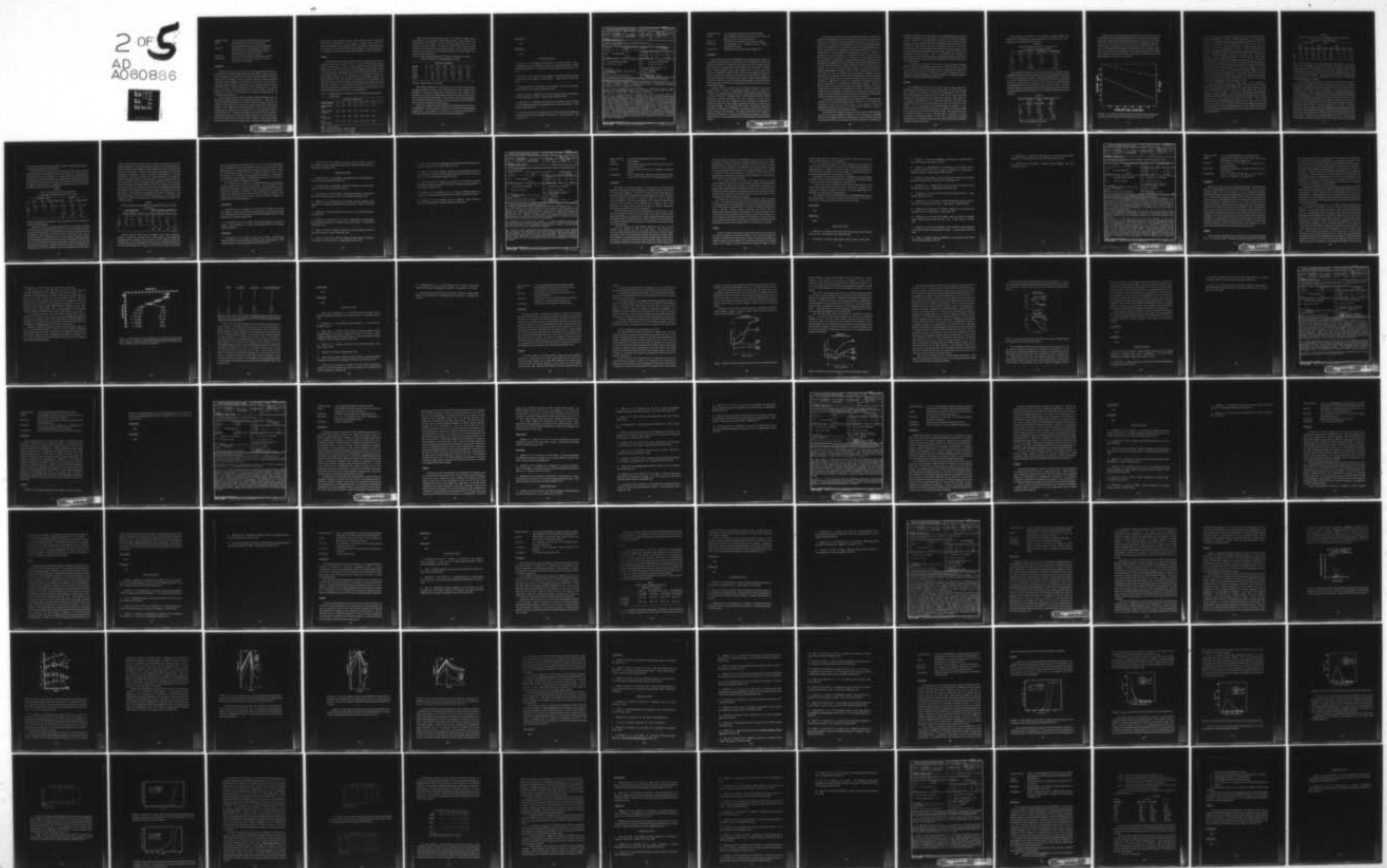

OF 5

0886

| | |
|---|---|
| Program Element: | 6.11.02A DEFENSE RESEARCH SCIENCES, ARMY |
| Project: | 3E161102BS08 Environmental Stress, Physical Fitness and Medical Factors in Military Performance |
| Work Unit: | 002 Development and Characterization of Models to Study Acute Mountain Sickness and High Altitude Pulmonary Edema in Military Operations |
| Study Title: | Effect of Altitude on the Body Fluid Spaces of the Rat |
| Investigators: | Allen Cymerman, Ph.D., SSG Adrien R. Lussier and SP4 Deborah J. Richardson |

Background:

During the first few days of exposure to altitudes above 2500 meters, unacclimatized human subjects display physical and psychological symptoms that have been combined under the heading of acute mountain sickness (AMS). This illness is characterized by headache, anorexia, vomiting, lassitude, dizziness, weakness, irritability, impaired judgment, and inability to concentrate. The occurrence of AMS during field maneuvers or combat situations at high altitude has an obvious detrimental effect on military performance, since symptoms occur at a crucial time for successful mission accomplishment (6 hours to 6 days). Although the phenomenon of AMS is well described, the mechanism(s) responsible for the symptoms remain(s) obscure.

Several studies (1,2) have implicated changes in body fluid compartments with AMS symptomatology because of a similar temporal course. Within hours of exposure to high altitude there is an increase in hematocrit which is due not to an increase in red cell mass but to a contraction of plasma volume (3,4). With minimal changes in body weight and no large alterations in total body water content, intravascular and interstitial water compartments are reduced after 48 hours of altitude exposure (1). Similarly, investigators have shown that the reduction in aldosterone excretion may be correlated with the presence of AMS symptoms (5). Using rats, Christensen et al. (6) have shown a change in brain wet-dry weight ratios during the first 24 hours of hypoxia which is indicative of an increase in brain

water content. Thus, evidence is present which indicates that the intracellular movement of fluid during the initial stages of altitude exposure may be of paramount importance in the etiology of AMS. This project is concerned with the use of the rat for the development and characterization of an animal model system to investigate the importance of altitude-induced changes in fluid compartments.

Progress

The initial phase of this study consisted of determining the extent of changes in water content of various organs in the rat. To this end, blood and four selected organs were examined in a series of timed exposures to simulated high altitude (5486 meters). Results indicate that maximum hemoglobin and hematocrit changes of 17.8 and 46.3 g %, respectively, were attained within 48 hours (Table 1). This most probably reflects the shift of plasma from the intravascular compartment. These increases, however, are not associated with any substantial changes in red blood cell (RBC) count. The reason for this observation is as yet unknown. The mean RBC volume, derived by dividing the hematocrit by the RBC count, does indicate an increase in red cell volume ($6.92 \times 10^{-6}$ $mm^3$ to $8.43 \times 10^{-6}$ $mm^3$). Since this measurement is independent of the reduction in plasma volume, it most likely represents movement of water into the red blood cell.

TABLE 1. HEMATOLOGICAL CHANGES OF RATS EXPOSED TO 5486 METERS ELEVATION

| | HOURS OF EXPOSURE | | | | | | |
|---|---|---|---|---|---|---|---|
| MEASUREMENT | 0 | 8 | 16 | 24 | 32 | 40 | 48 |
| HEMOGLOBIN (g %) | 15.6 | 16.3 | 17.2 | 17.0 | 17.8 | 17.3 | 17.6 |
| HEMATOCRIT (vol %) | 42.4 | 43.6 | 44.4 | 44.3 | 46.1 | 44.7 | 46.3 |
| RBC ($\times 10^6/mm^3$) | 6.11 | 5.54 | 5.96 | 6.48 | 5.49 | 6.28 | 5.73 |
| MCV ($\times 10^{-6} mm^3$) | 6.92 | 7.92 | 7.44 | 6.86 | 8.43 | 7.34 | 8.12 |

RBC = red cell count

MCV = mean cell volume = hematocrit/RBC

Values represent means of 5 or 6 animals

Table 2 shows the mean percent changes in wet weight-dry weight ratios in various organs of rats exposed to 5486 meters altitude. Several trends can be discerned from these results. The brain and lung weights appear to be most affected by altitude exposure. The increase in water content is approximately double that for kidney and heart at 32 hours exposure. Also, 32 hours may be a crucial time with respect to intracellular fluid shifts, since values appear to be returning toward initial levels.

TABLE 2. MEAN PERCENT CHANGES* IN WATER CONTENT OF ORGANS OF RATS EXPOSED TO 5486 METERS ELEVATION

| | HOURS OF EXPOSURE | | | | | | |
|---|---|---|---|---|---|---|---|
| ORGAN | 0 | 8 | 16 | 24 | 32 | 40 | 48 |
| BRAIN | 0 | 4.33 | 3.64 | 5.47 | 16.63 | 10.02 | 11.39 |
| LUNG | 0 | 6.96 | 8.12 | 9.05 | 16.24 | 20.19 | 14.62 |
| KIDNEY | 0 | 5.87 | 3.42 | 3.91 | 7.82 | 6.85 | 5.38 |
| HEART | 0 | 1.68 | 3.12 | 3.12 | 9.35 | 8.15 | 7.43 |

*Percent change relative to "O" hours

These results indicate that a reduction occurs in the plasma compartment with initial exposure to altitude. This is illustrated by the rise in hematocrit and hemoglobin. Furthermore, it appears that tissues differ in their responses to the altitude stress with brain and lung showing the largest increases in water content. These preliminary results lend support to the premise that the symptomatology of AMS and high altitude pulmonary edema may be directly related to the changes in the water content of brain and lung parenchyma.

Studies are in progress to measure the body fluid compartments with the use of radioisotopes in order to assess the changes in the extracellular and intracellular compartments. The feasibility of drug use as a means of preventing the intracellular movement of fluid is also currently being contemplated.

Presentations:

None.

Publications:

None.

## LITERATURE CITED

1. Shields, J. L., J. P. Hannon, R. P. Carson, K. S. K. Chinn, and W. O. Evans. Pathophysiology of acute mountain sickness. In: Biomedical Problems of High Terrestrial Elevations. U. S. Army Res. Inst. Environ. Med., Natick, MA, pp. 9-23, 1967.

2. Surks, M. I., S. K. Chinn, and L. R. O. Matoush. Alteration in body composition in man during acute exposure to high altitude. J. Appl. Physiol. 21:1741-1746, 1966.

3. Asmussen, E., and C. F. Consolazio. The circulation in rest and work on Mount Evans (4,300 m). Am. J. Physiol. 132:555-563, 1941.

4. Hannon, J. P., J. L. Shields, and S. K. Chinn. Effect of altitude acclimatization on blood composition of women. J. Appl. Physiol. 26:540-547, 1969.

5. Hogan, R. P., T. A. Kotchen, A. E. Boyd, and L. H. Hartley. Effect of altitude on renin-aldosterone system and metabolism of water and electrolytes. J. Appl. Physiol. 35:385-390, 1973.

6. Christensen, B. M., H. L. Johnson, and A. V. Ross. Organ fluid changes and electrolyte excretion of rats exposed to high altitude. Aviat. Space Environ. Med. 46:16-20, 1975.

(82005)

| RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY | | 1. AGENCY ACCESSION* | 2. DATE OF SUMMARY* | REPORT CONTROL SYMBOL |
|---|---|---|---|---|
| | | DA OB 6145 | 77 10 01 | DD-DR&E(AR)636 |

| 3. DATE PREV SUM'RY | 4. KIND OF SUMMARY | 5. SUMMARY SCTY* | 6. WORK SECURITY* | 7. REGRADING* | 8a. DISB'N INSTR'N | 8b. SPECIFIC DATA-CONTRACTOR ACCESS | 9. LEVEL OF SUM |
|---|---|---|---|---|---|---|---|
| 77 09 02 | D. Change | U | U | NA | NL | [X] YES [ ] NO | A. WORK UNIT |

| 10. NO./CODES:* | PROGRAM ELEMENT | PROJECT NUMBER | TASK AREA NUMBER | WORK UNIT NUMBER |
|---|---|---|---|---|
| a. PRIMARY | 6.11.02.A | 3E161102BS08 | 00 | 005 |
| b. CONTRIBUTING | | | | |
| c. ~~XXXXXXXX~~ | CARDS 114f | | | |

11. TITLE (Precede with Security Classification Code)*
(U) Models of Heat Disabilities: Preventive Measures (22)

12. SCIENTIFIC AND TECHNOLOGICAL AREAS*
016200 Stress Physiology; 005900 Environmental Biology; 003500 Clinical Medicine

| 13. START DATE | 14. ESTIMATED COMPLETION DATE | 15. FUNDING AGENCY | 16. PERFORMANCE METHOD |
|---|---|---|---|
| 76 10 | CONT | DA | C. In-House |

17. CONTRACT/GRANT
a. DATES/EFFECTIVE: EXPIRATION:
b. NUMBER:* NOT APPLICABLE
c. TYPE: d. AMOUNT:
e. KIND OF AWARD: f. CUM. AMT.

| 18. RESOURCES ESTIMATE | | a. PROFESSIONAL MAN YRS | b. FUNDS (In thousands) |
|---|---|---|---|
| FISCAL YEAR | PRECEDING 77 | 5.4 | 242 |
| | CURRENT 78 | 6.1 | 208.1 |

19. RESPONSIBLE DOD ORGANIZATION
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TELEPHONE: 955-2811

20. PERFORMING ORGANIZATION
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TELEPHONE: 955-2871
SOCIAL SECURITY ACCOUNT NUMBER:
ASSOCIATE INVESTIGATORS
NAME: HUBBARD, Roger, Ph.D.
NAME: FRANCESCONI, Ralph P., Ph.D. DA

21. GENERAL USE
Foreign Intelligence Not Considered

22. KEYWORDS (Precede EACH with Security Classification Code) (U) Environmental, Exercise Hyperthermia; (U) Creatine Phosphokinase Lactate; (U) Vasodilation

23. TECHNICAL OBJECTIVE,* 24. APPROACH, 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)

23. (U) The use of model systems to study the effectiveness of various measures designed to prevent, forestall or reduce the disabilities, injuries or performance decrements associated with military operations in the heat.

24. (U) A variety of suggested preventive measures e.g. prehydration, dietary supplementation and pharmacological agents will be evaluated in animal models for their effectiveness in forestalling or protecting from heat injury.

25. (U) 76 10 - 77 09 Rats were run on a treadmill (9.14 m $min^{-1}$) in the heat (35$^{\circ}$C) to a critical rectal temperature (42.5$^{\circ}$C). Following heat injury serial blood samples were taken to study the pathophysiochemical correlates of the injury and means by which these aberrations might be attenuated. In a blood sample taken immediately after the treadmill run, levels of plasma lactate ($p<.001$) and potassium ($p<.005$) were inversely correlated to ensuing survival times while no relationship was observed for creatine phosphokinase (CPK). When fluids were administered to forestall the heat injury, correlates of injury were similarly repressed; however, in a final blood sample taken at death, lactate, CPK, and potassium levels were all significantly increased ($p<.01$). Pre-treatment with nicotinic acid, a peripheral vasodilator, was ineffective in increasing heat loss from the tail. The administration of dextrose and insulin failed to repress the lactacidemia; similarly, the hormone dehydroepiandrosterone, reported to protect against the adverse effects of heat, had no effect on the survivability of the injured animals. Cortisone acetate, reported to be a membrane stabilizer, had no repressive effects on the efflux of CPK, lactate of potassium.

*Available to contractors upon originator's approval

| | |
|---|---|
| Program Element: | 6.11.02.A DEFENSE RESEARCH SCIENCES, ARMY |
| Project: | 3E161102BS08 Environmental Stress, Physical Fitness, and Medical Factors in Military Performance |
| Work Unit: | 005 Models of Heat Disabilities: Preventive Measures |
| Study Title: | Thermoregulatory and Pathophysiochemical Studies in Hyperthermic Animals |
| Investigators: | Ralph Francesconi, Ph.D. and Milton Mager, Ph.D. |

Background:

For several years we have investigated in rats thermoregulatory responses to the peripheral administration of amino acids (1) and salicylate (2) as well as the central administration of monoamines and drugs which affect monoamine action (3). The majority of experiments were performed under cold (4$^{o}$C) or moderate (22$^{o}$C) ambient conditions using either normal rats or animals fitted with permanent, indwelling cerebroventricular cannulae. Thus, hypothermic and hyperthermic responses were achieved in animals that were normothermic initially. In the present experiments we extended these studies to animals made hyperthermic by exercise in the heat to determine whether pharmacological or alternative therapeutic intervention could reduce the pathological effects and potential lethality of extreme hyperthermia.

Exposure of men or animals to hot environmental conditions or heavy work regimens elicits a number of physiological responses which are directed to reduction of core temperature; in humans these include peripheral vasodilation with a concurrent increase in sweating, while in animals hyperventilation, increased blood flow to the tail, and salivation may occur. However, if the heat load is sufficiently large, then these adaptations may be inadequate to attenuate the resultant hyperthermia and the attendant pathological correlates of cellular, tissue, and organal damage. Such pathological effects may be manifested in significant increments and inbalances in circulating constituents including certain enzymes, cations, hormones, and substrates. The present experiments were designed to determine the feasibility of reducing the physiological, pathological, and physiochemical effects of extreme hyperthermia by pharmacological, hormonal, and fluid therapy.

For example, in both animals and man, peripheral vasodilation is an important adaptation in dissipating heat to the environment. Several reports in the literature have attested to a reversal in this heat dissipatory mechanism under specific conditions; thus, a shutdown in skin vasodilation may have led to pathological hyperthermia in the following cases. In their recent report on malignant hyperpyrexia in animals susceptible to the hyperthermic stress syndrome, Williams, et al. (4) demonstrated an intense peripheral vasoconstriction creating an inability to dissipate heat which ultimately led to hyperthermic death. Hellstrom (5) has demonstrated in rats that when the core temperature is raised beyond 39°C, tail skin vasodilation is superseded by a reduction in skin blood flow leading to rapidly elevating core temperature. Even in well-conditioned marathon runners Adams, et al. (6) recently demonstrated a marked reduction in cutaneous blood flow during maximal runs in a hot environment, again leading to an intense hyperthermic response necessitating termination of the run. Thus, it appears that in both rats and humans the drive to dissipate heat by peripheral vasodilation may be superseded by a shutdown in this cooling mechanism under conditions combining work and heat and after specific skin and rectal temperatures have been attained. Therefore, it appeared to us useful to investigate pharmacological means to prevent development of vasoconstriction under these conditions. Hence, the salutary effects of nicotinic acid, not only as a peripheral vasodilator, but also as an agent which was effective in retaining plasma volume in thermally traumatized animals (7), were investigated. The ability to retain and increase vascular volume during acute thermal exposure has been identified recently by Senay and Kok (8) as important to the heat tolerance mechanism of human test subjects.

In yet another recent publication, Tal and Sulman (9) have demonstrated that injection with 50 mg dehydroepiandrosterone (DHEA) per day protected rats maintained at 37°C from the lethal effects of heat exposure. Thus, the hypothetical protective effects of the steroid hormone DHEA were tested in animals made hyperthermic by exercise in the heat.

Consideration of the salutary effects of steroid hormones raised another point which we have recently addressed. Elevation of core temperature for prolonged periods of time usually results in the denaturation of structural protein which may have deleterious effects on the integrity of the cell membrane. Such effects are

ordinarily manifested in extreme elevations in circulating plasma levels of cellular constituents originating in affected organs, especially liver, kidney, and skeletal muscle. Increases in these substances, e.g., lactate, urea nitrogen, enzymes, potassium ions, have long been identified as pathological indices of heat injury with correlations implied between the level of elevation and extent of the injury. Besides the steroid hormones, several non-steroidal, anti-inflammatory agents such as indomethacin and phenylbutazone (10) have been reported to repress protein denaturation induced by heat. Thus, we hypothesized that treatment of experimental animals with non-steroidal or steroidal agents during the development of acute hyperthermia might reduce the pathophysiochemical effects of heat injury at the cellular level.

In summation, we evaluated the efficacy of various therapeutic regimens designed to reduce the pathological manifestations of exercise in the heat. While the mechanisms of action of these agents were not interrelated and ranged from dilatory effects on arterioles to stabilization of cellular membranes, they were linked by a hypothetical potential to beneficial effects on the pathophysiology of exercise and environmentally induced hyperthermia.

Progress:

Rats weighing from 250g to 350 g were fitted with right jugular vein catheters, rectal thermistors, and tail-skin thermocouples. All rats were exercised on a treadmill at 9.14 m/min at an environmental temperature of $34.5 \pm 0.5^{\circ}C$. Thus, rectal temperatures (Tre) of $42.5^{\circ}C$ to $43.0^{\circ}C$ and skin temperatures (Tsk) ranging to $39^{\circ}C$ were assured by the experimental conditions. Upon cessation of the exercise approximately 1.5 ml of blood was withdrawn and animals were maintained at $34.5^{\circ}$ for 60 minutes, after which they were removed to $22^{\circ}C$ ambient. At the time of death, a second blood sample was obtained. In cases wherein the animal lived significantly beyond 60 minutes, three blood samples (post-treadmill, at 60 minutes and at death) were taken. This procedure permitted an accurate description of events occurring between attainment of maximal temperature and heat-caused death. In each case, concentrations of plasma constituents were corrected for hemoconcentration based upon the first hematocrit reading for the particular animal.

Among fatalities, hematocrits were significantly increased between the cessation of the treadmill run and heat induced death while total protein concentrations were not significantly affected (Table 1).

TABLE 1

Effects of Heat Injury on Levels of Hematocrit and Total Protein in Serial Blood Samples

| | $HCT_1$ | $HCT_2$ | TOT $PROT_1$ | TOT $PROT_2$ |
|---|---|---|---|---|
| n | 44 | 44 | 44 | 44 |
| X | 40.2 | 47.9 | 5.37 | 5.23 |
| SDx | 4.7 | 7.7 | 0.55 | 0.63 |
| SEx | 0.7 | 1.2 | 0.08 | 0.10 |
| t | --- | -10.97 | --- | 1.462 |
| p | --- | < .001 | --- | NS |

We recently demonstrated (11) that in man exercising in the heat, creatine phosphokinase (CPK) is the plasma enzyme which was most consistently elevated as a result of the heat/exercise regimen. In the present experiments, it is interesting to note that immediately after the treadmill run, values for CPK were significantly increased over control levels. However, at the time of death, the CPK levels had decreased significantly from the maximal values as noted in Table 2. The large standard deviations among exercised rats are not unusual, and are due partially to extreme variations in baseline levels and to interindividual differences in exercise responses.

TABLE 2

Effects of Exercise in the Heat on Plasma Levels of CPK

| | CPK* Normal | $CPK_1$ Post-Tread | $CPK_2$ Final |
|---|---|---|---|
| n | 10 | 44 | 44 |
| X | 84.1 | 518.4 | 366.9 |
| SDx | 32.5 | 667.2 | 501.7 |
| SEx | 10.3 | 100.6 | 75.6 |
| t | --- | 2.04 | 3.306 |
| p | --- | < .05 | < .005 |

*CPK - International Units per Liter

Among the most interesting aspects of this portion of the study is the most highly significant inverse correlation between lactate and potassium concentrations in the initial blood samples (post-treadmill) and the survival time for the heat-injured rats. For lactate concentrations in 60 rats, the correlation coefficient r between lactate concentration and survival time was -0.6795 giving rise to a t value of 7.053 and $p<0.001$; analogously, for potassium ($K^+$) the correlation coefficient r was -0.402 with a corresponding t value of 3.285 and $p<0.005$. As expected, the correlation between initial lactate and potassium concentrations was also highly significant ($r = 0.6632$, $t = 6.63$, $p<.001$).

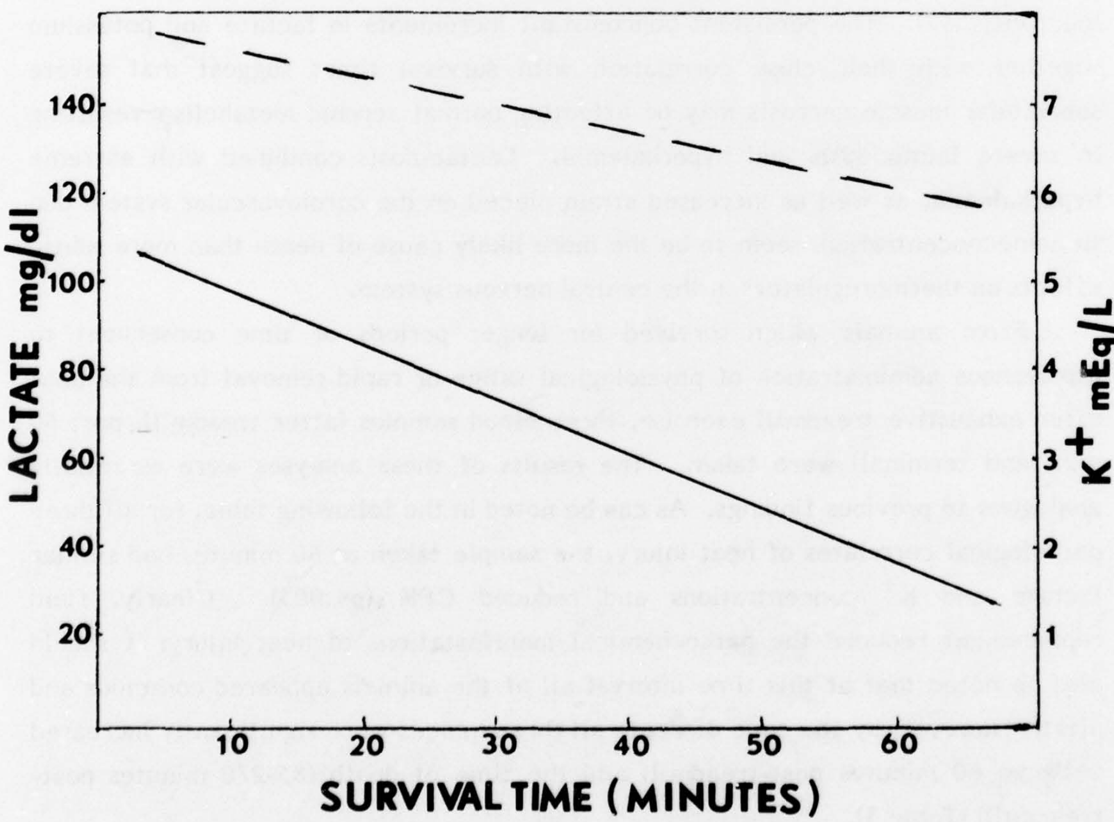


FIGURE 1. Least Squares Regression Analysis:Correlation of Lactate Concentration (solid line) and Potassium Concentration (broken line) to Survival Time

Survival time after heat and treadmill induced injury was not correlated to CPK values (post-treadmill) ($r = -0.1444$, $t = 1.082$, not significant). It is interesting to note that for CPK levels, values decreased significantly between the time when animals were removed from the treadmill and the time of death. This was anticipated since the rats were lying quietly in restraining cages during this interval at an ambient temperature of 34.5°C. Cooling was slow and heat associated denaturation of enzymatic protein might also have contributed to such a reduction. However, during the same crucial period, levels of lactate and potassium increased significantly ($p<.001$). This observation raises several important points with respect to heat/exercise induced injury since it might have been expected that levels of lactate and $K^+$ would decrease during this period of inactivity (12). The persistent concomitant increments in lactate and potassium together with their close correlation with survival times suggest that severe subcellular muscle necrosis may be affecting normal aerobic metabolism resulting in severe lactacidosis and hyperkalemia. Lactacidosis combined with extreme hyperkalemia, as well as increased strain placed on the cardiovascular system due to hemoconcentration, seem to be the more likely cause of death than more subtle effects on thermoregulators in the central nervous system.

From animals which survived for longer periods of time consequent to intravenous administration of physiological saline or rapid removal from the heat after exhaustive treadmill exercise, three blood samples (after treadmill, post 60 min, and terminal) were taken. The results of these analyses were essentially analogous to previous findings. As can be noted in the following table, for all three pathological correlates of heat injury, the sample taken at 60 minutes had similar lactate and $K^+$ concentrations and reduced CPK ($p<.005$). Clearly, fluid replacement reduced the pathochemical manifestations of heat injury; it should also be noted that at this time interval all of the animals appeared conscious and alert. However, by the time of death all three indices were significantly increased between 60 minutes post-treadmill and the time of death (85-270 minutes post-treadmill) (Table 3).

TABLE 3

Effects of Exercise in the Heat on Pathophysiochemical Correlates of Heat Injury in Serial Blood Samples

| | LACTIC ACID | | | CPK | | | $K^+$ | | |
|---|---|---|---|---|---|---|---|---|---|
| | Post-Tread | 60 Min | Death | Post-Tread | 60 Min | Death | Post-Tread | 60 Min | Death |
| n | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
| X | 27.4 | 25.9 | 94.3 | 523 | 253 | 804 | 6.3 | 6.1 | 11.1 |
| SDx | 8.9 | 11.4 | 38.4 | 313 | 92 | 375 | .6 | 1.0 | 3.9 |
| SEx | 2.8 | 3.6 | 12.1 | 99 | 29 | 119 | .2 | .3 | 1.2 |

These highly significant increases ($p<.005$) again demonstrate severe adverse effects on muscle metabolism and possibly the ability of the liver to resynthesize glycogen from lactate. Hematocrits at 60 min were similarly low due to fluid intervention, but in 7 out of 10 animals, hematocrits had increased to $56.1 \pm 1.05\%$ by the time of death (initial HCT = 43%). In animals not demonstrating increased final hematocrits ($n = 3$, mean = 43%) values for lactic acid, $K^+$, and CPK were nonetheless significantly increased.

To test whether steroidal and non-steroidal anti-inflammatory compounds could reduce the pathological effects of exhaustive exercise in the heat, several experiments were performed using various concentrations of cortisone acetate and indomethacin administered either intravenously or intraperitoneally prior to treadmill exercise. Neither compound was effective in attenuating any physiological or pathological effects of heat/exercise induced hyperthermia. We anticipated that cortisone acetate, in particular, would reduce the efflux of CPK and $K^+$ from muscle tissue during exercise; however, no significant differences were noted in groups of animals injected prior to run with either 5.0 mg cortisone acetate in 1.5 ml of normal saline or simply 1.5 ml normal saline (CPK, $t = 1.534$; $K^+$, $t = .087$, not significant). Similarly, despite reports (9) suggesting that dehydroepiandrosterone may be an effective prophylactic regimen for animals exposed passively to acute heat stress, in exercising animals no beneficial effects of either pre-treatment for several days or injection prior to experimentation were noted. Skin and rectal temperatures, treadmill and survival times, total protein, CPK, $K^+$, and lactate

levels were all unaffected, thus confirming the balance of physiological, prophylactic and therapeutic benefits of this hormone.

Close monitoring of rectal and skin temperatures (one minute intervals) demonstrated that all pretreatment regimens were ineffective in accelerating the rate of body heat loss by vasodilation. For example, when animals pretreated with 100 mg nicotinic acid intravenously prior to treadmill exercise were compared with rats pretreated with hypertonic saline (due to necessity for using sodium hydroxide to solubilize nicotinic acid), the following table demonstrates that no significant physiological differences were noted (Table 4).

TABLE 4

Effects of Pretreatment with Nicotinic Acid on Thermoregulatory Responses to Exercise in the Heat

| | NICOTINIC ACID | | | 5% NaCl | | |
|---|---|---|---|---|---|---|
| | Tsk | Tre | Time on Tread | Tsk | Tre | Time on Tread |
| n | 14 | 14 | 14 | 11 | 11 | 11 |
| X | 36.7°C | 42.6°C | 36.9 min | 37.0°C | 42.8°C | 37.4 min |
| SDx | 1.5 | .7 | 7.1 | 1.7 | .6 | 8.5 |
| SEx | .4 | .2 | 1.9 | .5 | .2 | 2.6 |
| t | | | | 0.442 | .998 | .163 |
| p | | | | NS | NS | NS |

Similarly, pathochemical correlates as well as hematocrits were unaffected by nicotinic acid pretreatment.

Because of the level of correlation noted between lactate levels and survival time as well as the extremely high concentrations of lactic acid invariably observed at death, several experiments were performed in an attempt to repress lactic acid accumulation. The persistent increase in lactate concentration after exercise terminated could be a manifestation of one of the following: a metabolic derangement preventing reconversion of pyruvate to glucose and glycogen, continual breakdown of muscle protein permitting the accumulation of alanine and hence pyruvate and lactate, accumulation of reduced nicotinamide adenine dinucleotide due to disturbances in the electron transport chain thus increasing the concentration of

reduced substrates (lactate), greatly reduced insulin levels leading to fatty acid oxidation giving rise to decreasing pyruvate oxidation, thus increasing pyruvate, lactate, and alanine accumulation, or reduced oxidation of lactate to $CO_2$ by heart, muscle, liver, and kidney. Because several reports have appeared recently (13) suggesting the efficacy of insulin and glucose administration for reducing lactacidemia in both humans and animals, several experiments were designed to evaluate the beneficial effects of such treatment. In one such experiment six rats were removed from the heat immediately upon completion of a run to exhaustion; within five minutes intravenous infusion with 2.0 ml containing 100 mg dextrose and 2 units of insulin was initiated. Control rats for this experiment were treated identically save for infusion with 2.0 ml normal saline. All infusions were carried out at 22°C. Table 5 presents a compilation of data from this experiment. The data presented here is for the second blood sample only - i.e., 60 minutes after completion of exercise and usually within 10 minutes following completion of the infusion procedure:

TABLE 5

Effects of Infusion of Dextrose/Insulin on Pathophysiochemical Correlates of Heat Injury

| | SALINE INFUSION | | | | DEXTROSE/INSULIN INFUSION | | | |
|---|---|---|---|---|---|---|---|---|
| | $CPK_{60}$ | $PROT_{60}$ | $LACT_{60}$ | $K^+_{60}$ | $CPK_{60}$ | $PROT_{60}$ | $LACT_{60}$ | $K^+_{60}$ |
| n | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 |
| X | 233 | 5.1 | 20.8 | 6.1 | 348 | 5.0 | 19.2 | 4.5 |
| SDx | 141 | .6 | 12.0 | .8 | 178 | .4 | 19.0 | .6 |
| SEx | 58 | .2 | 5.0 | .3 | 73 | .2 | 7.7 | .3 |
| t | --- | | | | 1.24 | .35 | .17 | 3.37 |
| p | | | | | NS | NS | NS | p<.01 |

Several important observations are apparent from these experiments. Initially, it should be noted that many of these animals survived indefinitely although they were exercised to Tre's in excess of 42.5°C. However, infusion with destrose/insulin was not responsible for the survival rate because animals infused with NaCl did equally as well. Clearly, the combination of removal from the heat

and fluid administration were the key factors. It may also be noted that infusion with dextrose/insulin did not significantly repress lactate accumulation; fluid administration per se was sufficient to repress the anticipated increments. Finally, the dextrose/insulin infusion did have a significant repressive effect on the concentration of $K^+$ in plasma by an undetermined mechanism. Considering the close correlation between degree of hyperkalemia and survival time this observation may warrant further investigation in the future.

It is anticipated that research on the pathophysiological and pathophysiochemical correlates of heat injury will continue. An understanding of these aberrancies will continue to provide information for devising suitable preventive measures and therapeutic intervention. Close monitoring of the pathochemical changes occurring during the course of heat injury will afford information on the actual cause of the injury and, of course, results will continue to suggest new methods for prevention and treatment.

<u>Presentations:</u>

1. Francesconi, R. P., J. T. Maher, G. D. Bynum, and J. W. Mason. Recurrent heat exposure: effects on enzyme and potassium efflux in resting and exercising men. Federation of American Societies for Experimental Biology. Spring Meeting, Chicago, 1977. (Fed. Proc. 36:433, 1977).

2. Francesconi, R. P. and J. T. Maher. Perceptual advantages of heat acclimatization. Annual Meeting of the American Physiological Society, Fall Meeting, Hollywood Beach, FL.

<u>Publications:</u>

1. Francesconi, R. P., J. Maher, G. Bynum, and J. Mason. Recurrent heat exposure: effects on levels of plasma and urinary sodium and potassium in resting and exercising men. Avia. Space Environ. Med. 48:399-404, 1977.

2. Franceschoni, R. P., J. T. Maher, G. D. Bynum and J. W. Mason. Recurrent heat exposure: effects on enzymatic alterations in resting and exercising men. J. Appl. Physiol. 43:308-311, 1977.

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1. Francesconi, R. P. and M. Mager. L-tryptophan: effects on body temperature in rats. Amer. J. Physiol. 227:402-405, 1974.

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11. Francesconi, R. P., J. T. Maher, G. D. Bynum, and J. W. Mason. Recurrent heat exposure: effects on enzymatic alterations in resting and exercising men. J. Appl. Physiol. 43:308-311, 1977.

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(82009)

**RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY**

| 1. AGENCY ACCESSION* | 2. DATE OF SUMMARY* | REPORT CONTROL SYMBOL |
|---|---|---|
| DA OB 6120 | 77 10 01 | DD-DR&E(AR)636 |

| 3. DATE PREV SUM'RY | 4. KIND OF SUMMARY | 5. SUMMARY SCTY* | 6. WORK SECURITY* | 7. REGRADING* | 8a. DISB'N INSTR'N | 8b. SPECIFIC DATA-CONTRACTOR ACCESS | 9. LEVEL OF SUM |
|---|---|---|---|---|---|---|---|
| 76 10 01 | D. Change | U | U | NA | NL | ☒ YES ☐ NO | A. WORK UNIT |

| 10. NO./CODES:* | PROGRAM ELEMENT | PROJECT NUMBER | TASK AREA NUMBER | WORK UNIT NUMBER |
|---|---|---|---|---|
| a. PRIMARY | 6.11.02.A | 3E161102BS08 | 00 | 009 |
| b. CONTRIBUTING | | | | |
| c. XXXXXXXX | CARDS 114f | | | |

11. TITLE (Precede with Security Classification Code)*

(U)Biological Processes that Limit Heavy Physical Work Ability of the Soldier (22)

12. SCIENTIFIC AND TECHNOLOGICAL AREAS*

012900 Physiology

| 13. START DATE | 14. ESTIMATED COMPLETION DATE | 15. FUNDING AGENCY | 16. PERFORMANCE METHOD |
|---|---|---|---|
| 70 07 | CONT | DA | C. In-House |

17. CONTRACT/GRANT

a. DATES/EFFECTIVE: EXPIRATION:

b. NUMBER:* NOT APPLICABLE

c. TYPE: d. AMOUNT:

e. KIND OF AWARD: f. CUM. AMT.

| 18. RESOURCES ESTIMATE | | a. PROFESSIONAL MAN YRS | b. FUNDS (In thousands) |
|---|---|---|---|
| FISCAL YEAR | PRECEDING 77 | 3.5 | 95 |
| | CURRENT 78 | 1.8 | 65.8 |

19. RESPONSIBLE DOD ORGANIZATION

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RESPONSIBLE INDIVIDUAL

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20. PERFORMING ORGANIZATION

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PRINCIPAL INVESTIGATOR (Furnish SSAN if U.S. Academic Institution)

NAME:* VOGEL, James A., Ph.D.

TELEPHONE: 955-2800

SOCIAL SECURITY ACCOUNT NUMBER:

ASSOCIATE INVESTIGATORS

NAME: PATTON, John F., Ph.D.

NAME: 955-2879

DA

21. GENERAL USE

Foreign Intelligence Not Considered

22. KEYWORDS (Precede EACH with Security Classification Code) (U)High Intensity Exercise; (U)Anaerobic Work Capacity; (U)Anaerobic Metabolism; (U)Muscle Contraction

23. TECHNICAL OBJECTIVE,* 24. APPROACH, 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)

23. (U)The combat soldier often depends upon his ability to perform sustained and sometimes severe levels of muscular exertion. The objectives of this research are to a) identify and characterize those biological processes that influence his capacity to perform heavy work, thereby providing a rational basis for improving the soldier's performance; and b) identify the physiological and biochemical processes that occur during physical training both at the whole body and muscle level, thereby providing a rational basis for improving physical training programs.

24. (U)Specific areas of study will include: (1) Anaerobic metabolism during high intensity exercise; (2) Measures of anaerobic power/fitness; (3) Develop training methods for anaerobic fitness; and (4) Biochemical and morphologic changes in skeletal muscel during training of various intensities and frequency.

25. (U)76 10 - 77 09 A specialized high intensity bicycle ergometer has been designed and is presently being constructed for the purpose of measuring anaerobic power capacity of human subjects. The bicycle will have a work load range of 1500 watts and employs a static direct current regenerative drive braking mechanism. This device serves as a clutch to permit momentum to be established before the load is applied to the subject. This will permit the use of work intensities limiting exercise performance to less than 10 seconds.

*Available to contractors upon originator's approval.

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|---|---|
| Program Element: | 6.11.02.A DEFENSE RESEARCH SCIENCES, ARMY |
| Project: | 3E161102BS08 |
| Work Unit: | 009 Biological Processes that Limit Heavy Physical Work Ability of the Soldier |
| Study Title: | Anaerobic Power Production as a Component of Physical Fitness |
| Investigators: | James A. Vogel, Ph.D., Howard G. Knuttgen, Ph.D., Michael J. Sacco, John F. Patton, Ph.D. and Kent B. Pandolf, Ph.D. |

Background:

The ability of the human organism to sustain physical activity involving repetitive contractions of large muscle groups is inversely related to the force of the contractions employed. In exercise involving concentric (shortening) contractions, activity may be maintained for a period longer than an hour if the force of each contraction amounts to 15 percent or less of a maximal voluntary contraction (MVC) of the active muscle groups. When contractions exceed 20-25 percent of MVC, exercise can be sustained for 5 minutes or less. When contractions of greater than 50 percent of MVC are repeated rhythmically, endurance time is limited to a matter of seconds (13).

Exercise intensities which may be maintained for extended periods of time have been extensively studied as has been exercise that elicits maximal oxygen uptake (and fatigue in 3-10 minutes) (14). Studies involving high intensity exercise with repeated contractions greater than 50 percent MVC are virtually nonexistent, the principal reason being the unavailability of instrumentation to produce the high power loads necessary.

A person's capacity for high intensity exercise is, for the most part, dependent upon anaerobic processes for energy release. The involvement of anaerobic energy release processes in exercise has been rather extensively studied but chiefly in terms of the oxygen debt mechanism and patterns of oxygen uptake. These studies have employed exercise intensities utilizing muscle contractions in the range of 5-25 percent of MVC (1-8). Rate of anaerobic energy release has also been studied in experiments involving treadmill running and lactate appearance in

the blood (an indirect measure of anaerobiosis) but never in terms of complete exhaustion and, therefore, capacity for anaerobic energy released (9-11). Moderately high exercise intensities, in the range of 20-35 percent of MVC, have been studied in terms of muscle fiber type utilization but the determination of capacity for power production (or endurance) was not included in the protocol (12). Although the capacity of the human organism for anaerobic exercise constitutes an important area of investigation with great practical implications, it has been given little attention by the scientific community.

A list of typical anaerobic activities would include sprinting up a steep incline, walking or running with a heavy load (e.g., weapons and ammunition), and heavy lifting. The daily activity schedule of a combat soldier, therefore, involves numerous bouts of high-intensity anaerobic physical exercise. The assessment of an individual's functional capacity for anaerobic exercise and the design of developmental exercise programs for anaerobic power potential have been severely hampered by the absence of research information.

The objectives of this study are: (1) design and construction of an ergometer on which a full range of exercise intensities may be obtained, including intensities limiting physical performance (endurance) to less than 10 seconds; (2) establishment of the relationships and reproducibility or test-retest reliability among aerobic exercise capacities, anaerobic exercise capacities, and strength (MVC) for representative military personnel; (3) development of a theoretical model on which to base further study of anaerobic power capacity and high intensity exercise, i.e., the relationship of anaerobic power capacity to performance of military tasks, the role of anaerobic power capacity in the physical conditioning of the soldier, and the physiological mechanisms which support and/or limit anaerobic power capacity.

**Progress:**

The most commonly used devices for regulating large-muscle activity are the motor-driven treadmill and the bicycle ergometer. The motor-driven treadmill is incapable of producing the high exercise intensities desired and introduces two negative features: (a) the handicap to the research protocol that an uncontrolled change in the frequency of muscle contraction accompanies changes in running

speed and step frequency and (b) the safety feature of injury from fall to the subjects while running at extremely high speeds.

The cycle ergometer constitutes an ideal instrument for producing the full range of power production desired. Commercial models presently available are limited, however, to a range of 300 Watts or less. As exercise intensities up to 1500 Watts will be required for male test subjects of large physical stature, a specially designed ergometer for this purpose is necessary.

The design of a suitable ergometer has been completed and the power/braking mechanisms have been selected and procured. The fabrication of the bicycle frame itself has started and should be completed by November 1977.

A static direct current regenerative drive system (WER Industrial, Grand Island, NY) was selected for the clutch and drive control of the ergometer. This will permit the subject to establish momentum at the desired pedal rpm with no load before the selected load is suddenly applied.

The ergometer frame has been designed with interchangeable gear sizes to give a pedal range of 10-120 rpm and maximum load of 2000 watts. The ergometer can be used in either the concentric or eccentric mode of exercise.

Presentations:

None

Publications:

None

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(82011)

| RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY | | 1. AGENCY ACCESSION* | 2. DATE OF SUMMARY* | REPORT CONTROL SYMBOL |
|---|---|---|---|---|
| | | DA OC 6122 | 77 10 01 | DD-DR&E(AR)636 |

| 3. DATE PREV SUM'RY | 4. KIND OF SUMMARY | 5. SUMMARY SCTY* | 6. WORK SECURITY* | 7. REGRADING* | 8a. DISB'N INSTR'N | 8b. SPECIFIC DATA-CONTRACTOR ACCESS | 9. LEVEL OF SUM |
|---|---|---|---|---|---|---|---|
| 77 06 15 | D. Change | U | U | N/A | N/L | ☒ YES ☐ NO | A. WORK UNIT |

| 10. NO./CODES:* | PROGRAM ELEMENT | PROJECT NUMBER | TASK AREA NUMBER | WORK UNIT NUMBER |
|---|---|---|---|---|
| a. PRIMARY | 6.11.02.A | 3E161102BS08 | 00 | 011 |
| b. CONTRIBUTING | | | | |
| ~~XXXXXXXXX~~ | CARDS 114f | | | |

11. TITLE (Precede with Security Classification Code)*

(U) Assessment of the Impact of the Environment on Military Performance (22)

12. SCIENTIFIC AND TECHNOLOGICAL AREAS*

013400 Psychology; 005900 Environmental Biology; 002300 Biochemistry; 012900 Physiology

| 13. START DATE | 14. ESTIMATED COMPLETION DATE | 15. FUNDING AGENCY | 16. PERFORMANCE METHOD |
|---|---|---|---|
| 76 11 | CONT | DA | |

17. CONTRACT/GRANT

a. DATES/EFFECTIVE: EXPIRATION:

b. NUMBER:* NOT APPLICABLE

c. TYPE: d. AMOUNT:

e. KIND OF AWARD: f. CUM. AMT.

| 18. RESOURCES ESTIMATE | | a. PROFESSIONAL MAN YRS | b. FUNDS (In thousands) |
|---|---|---|---|
| FISCAL YEAR | PRECEDING 77 | 3.8 | 243 |
| | CURRENT 78 | 5.1 | 241.7 |

19. RESPONSIBLE DOD ORGANIZATION

NAME:* USA RSCH INST OF ENV MED

ADDRESS:* Natick, MA 01760

RESPONSIBLE INDIVIDUAL

NAME: DANGERFIELD, HARRY G., M.D., COL, MC

TELEPHONE: 955-2811

20. PERFORMING ORGANIZATION

NAME:* USA RSCH INST OF ENV MED

ADDRESS:* Natick, MA 01760

PRINCIPAL INVESTIGATOR (Furnish SSAN if U.S. Academic Institution)

NAME:* KOBRICK, John L., Ph.D.

TELEPHONE: 955-2855

SOCIAL SECURITY ACCOUNT NUMBER:

ASSOCIATE INVESTIGATORS

NAME: FINE, Bernard J., Ph.D.

NAME: 955-2874 DA

21. GENERAL USE

Foreign Intelligence Not Considered

22. KEYWORDS (Precede EACH with Security Classification Code) (U)Human Performance in Heat; (U)Human Performance in Cold; (U)Human Performance at Altitude; (U)Sustained Human Performance

23. TECHNICAL OBJECTIVE,* 24. APPROACH, 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)

23. (U) Prior to the development of frank casualties in situations involving extreme environments, prodromal symptoms occur which lead to performance deficiencies. The objective of this project is to develop a methodology to identify and analyze the principal military task components and personal characteristics of individual soldiers which are particularly influenced by exposure to extremes of heat, cold, and altitude, and by difficult and/or extended operations, and thereby affect the efficiency of functioning military systems.

24. (U) The methodology embodies high face validity - use of real military systems; actual military equipment and procedures; precise definition and measurement of tasks; systematic manipulation of environmental exposures and oeprational conditions; and, predictive validity - ability to generalize findings to actual Army operational field situations.

25. (U) 76 10 - 77 09 A first study of effects of 8-hour exposures to high altitude (4000 m) and hot-wet (35°C, 88%RH) conditions showed significant impairment of selected artillery FDC-type tasks (fire mission calculations, message coding, MET data recording). Altitude effects occurred early (within 1 hour) and subsequently abated. Heat effects developed more slowly and showed little or no recovery. A second study was conducted using the former and new tasks (higher work load), doubly extended training time, and lower heat-humidity (36.1°C, 73%RH). Similar altitude effects occurred again, with no recovery. Heat effects were less than before, possibly due to the lowered humidity and extended training time. Significant impairments were noted in map plotting and range estimation. Data collection has been completed in a third study of effects of heat-humidity exposure following a 15-hour simulated rapid translocation flight.

*Available to contractors upon originator's approval

DD FORM 1 MAR 68 1498 PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE. DD FORMS 1498A, 1 NOV 65 AND 1498-1, 1 MAR 68 (FOR ARMY USE) ARE OBSOLETE.

| | |
|---|---|
| Program element: | 6.11.02.A DEFENSE RESEARCH SCIENCES, ARMY |
| Project: | 3E161102BS08 Environmental Stress, Physical Fitness and Medical Factors in Military Performance |
| Work Unit: | 011 Assessment of the Impact of the Environment on Military Performance |
| Study Title: | Evaluation of Fasciotomy for Surgical Treatment of Frostbite in the Dog |
| Investigators: | Murray P. Hamlet, D.V.M., David R. Franz, CPT, VC, D.V.M., Joel J. Berberich, CPT, MSC, Ph.D. |

Background:

Failure of the microcirculation and resultant hypoxia have been implicated as the key in the pathogenesis of most clinical frostbite (1,3,8). Vascular stasis and peripheral ischemia have been attributed to a series of phenomena including endothelial pathology (1), and platelet aggregation as well as other coagulopathies (7,9). Increased tissue pressure, secondary to edema formation, may explain why traditional forms of chemotherapy alone have not been particularly effective (4). Mills & Edwards have suggested fasciotomy as a means of quickly and easily reducing the increased tissue pressure seen following rewarming of the frostbitten extremity (2,4). Fasciotomy has been used successfully to treat arterial/venous injury, massive soft tissue injury and other syndromes involving alteration of the normal distal circulation and associated massive swelling (6). Mills has been encouraged by his initial clinical experience in humans using fasciotomy along with vasodilators to treat frostbite (5). The objective of this study was to evaluate the effectiveness of fasciotomy and vasodilator therapy for frostbite in the dog model. Treatment techniques would be evaluated based on the measurement of foot volume, deep tissue temperature, tissue pressure, and tissue survival.

Progress:

Severe frostbite was produced in the left rear foot of 26 mongrel dogs ranging from 15 to 20 kg body weight. The dogs were divided into groups by the treatment

which each group received. Six dogs (group A) served as controls and received only the injury and daily therapy described below. Six dogs (group B) in addition to the basic therapy received 10mg phenoxybenzamine HCl (Dibenzyline, SKF) via gastric tube at the onset of rapid rewarming following the freezing injury and daily per os. Six dogs (group C) in addition to basic therapy received a fasciotomy at 30 minutes post thaw. Fasciotomy incisions extended (a) longitudinally on the medial and lateral aspects of the injured foot from just proximal to the hock to phalanx III, (b) on the plantar surface from approximately 3cm distal to the tubercalsus, to the metatarsal pad, and (c) on the dorsal surface over digits III and IV from mid metatarsal to the phalanx III. Eight dogs (group D) in addition to basic therapy received both phenoxybenzamine and fasciotomy.

Anesthesia was induced by intravenous administration of thiamylal (Surital$^R$, Parke Davis) and maintained with pentobarbital (Nembutal$^R$, Abbott Labs.). Dogs were placed in sternal recumbancy, with rear legs suspended over the end of a modified table. Phalangeal IM pins were transversed through the tuber calci, suspending the legs from supporting members extending from the end of the table. The left foot was covered with a rubber sleeve and a tourniquet palced on both feet just proximal to the hock.

The left foot was immersed in a -27 to -28$^{\circ}$C circulating ethylene glycol bath, to a level of 4.5cm distal to the point of the hock (the tarsal-metatarsal junction). The tourniquets remained on both rear feet for 100 minutes while the left foot was being freeze injured. Immediately after removal from the ethylene glycol bath, both tourniquets were removed, the rubber sleeve was removed from the left foot, and the left foot was rapidly rewarmed in a still water bath at 42$^{\circ}$C. Rewarming was considered complete when the deep temperature of the frozen extremity (left) equalled that of the contralateral (right) foot. Foot volume was measured by water displacement. Pressure was measured by a water manometer at a point midway between the skin and metatarsals on the plantar surface of the foot. Tissue pressure was recorded at 25-30 minutes and 1 hour post thaw. Throughout the entire freeze-thaw period and for 3 hours post thaw, bilateral deep foot temperatures and rectal temperatures were recorded on a Leeds and Northrup Speedomax$^R$ recorder. At 2½ to 3 hours post thaw, dogs were removed from the holding apparatus, modified Robert Jones bandages were applied to both rear legs,

and the dogs were returned to their cages to recover from anesthesia.

Daily nursing care included a 20 minute treatment in a 38°C water bath containing Povidone-Iodine Soln (Batadine Soln$^R$, Predue Fredrick Co.). A "whirlpool" effect was produced by bubbling compressed air through a tube in the bottom of the bath. Before each daily "whirlpool" treatment, deep foot temperatures and foot volumes were measured, and a photographic and written description of the condition of the injured extremity recorded. On days 1-3, all dogs received 300ml lactated ringer solution during the "whirlpool" therapy. After treatment, Robert Jones bandages were once again applied to both rear legs. Systemic antibacterial therapy was not used in any of the subjects in this study.

All 26 dogs received the injury and therapy described above and were maintained for 14 days post thaw, at which time a second radiograph was taken and the dogs were euthanized. Tissue survival was graded on a single blind basis on a scale from 0 to 9, total tissue loss to total tissue survival respectively based on the photographs and radiographs taken 14 days after the freezing injury.

Significant differences between fasciotomy and non-fasciotomy dogs were seen in foot temperature (Figure 1), volume and tissue pressure immediately following fasciotomy (not shown). Though there was no significant difference in 14 day tissue loss (Figure 2), there was significant prolongation of integrity of the local vascular system for 2-5 days following fasciotomy, and total foot salvage in several dogs receiving fasciotomy.

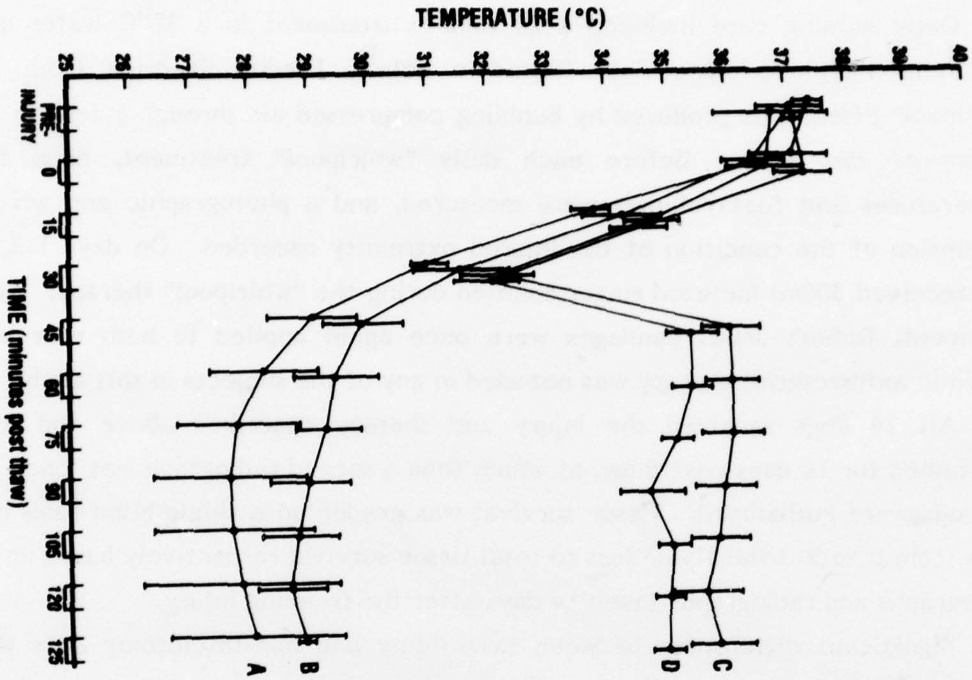


Figure 1. The temperature of the frostbitten paw is plotted against time after injury (post-thaw). Group A were controls; Group B received vasodilator after thaw. Groups C and D were treated by surgical fasciotomy at 30 minutes post-thaw. In addition, Group D also received vasodilator.

| | A Control | B Vasodilator | C Fasciotomy | D Fasciotomy/Vasodilator |
|---|---|---|---|---|
| | 5 | 6 | 8 | 9 |
| | 3 | 6 | 8 | 6 |
| | 3 | 5 | 3 | 5 |
| | 1 | 5 | 2 | 4 |
| | 1 | 3 | 1 | 2 |
| | 1 | 2 | 0 | 1 |
| | | | | 1 |
| | | | | 0 |
| $\bar{X}$ | 2.33 | 4.50 | 3.67 | 3.50 |
| $S_x$ | 1.63 | 1.64 | 3.50 | 3.07 |
| $S_{\bar{x}}$ | 0.67 | 0.67 | 1.43 | 1.09 |

Figure 2. Tissue Loss at 14 days was scored anatomically on a scale of 0 to 9, (from total foot loss to total survival). Although no differences between mean survival of the 4 groups was demonstrated, a few fasciotomy dogs only demonstrated remarkable tissue survival.

In spite of the less than remarkable overall tissue outcome, these data none-the-less support the thesis that fasciotomy may have a role in frostbite therapy. A pattern of tissue loss was apparent in the dog frostbite model: fasciotomy was either markedly successful or appeared to be counterproductive for tissue salvage. The very favorable results in several of the fasciotomy dogs is important because the injury produced in all animals was extremely severe, and resulted in autoamputation at the tarsal-metatarsal junction in control animals. Only the few dogs in groups C and D survived with an essentially intact foot after injury. Why the fasciotomy appeared to be an all or nothing therapy is not clear. The feet shich mummified early appear either to have to reestablish nutritive flow, or to have sustained direct effects of freezing of cells, or both. The feet which remained viable for 2-5 days post freeze, then deteriorated seem to have survived the direct effect of freezing, but succumbed to some later circulatory pathology. Further studies are necessary to increase our understanding of the pathophysiology leading to the breakdown of an apparently improved post-fasciotomy vascular system in the frostbitten limb.

Presentations:

None

Publications:

None

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|---|---|
| Program Element: | 6.11.02.A DEFENSE RESEARCH SCIENCES, ARMY |
| Project: | 3E161102BS08 Environmental Stress, Physical Fitness and Medical Factors in Military Performance |
| Work Unit: | 011 Assessment of the Impact of the Environment on Military Performance |
| Study Title: | The Separate Effects of Altitude and Heat on Sustained Performance of Simulated Artillery FDC Tasks |
| Investigators: | Bernard J. Fine, Ph.D. and John L. Kobrick, Ph.D. |

Background:

This project involves a continuation of previous research on the separate effects of heat and altitude on individual performance of cognitive tasks involved in artillery fire direction center (FDC) operations. The FDC is crucial to the effectiveness of artillery operations, and ultimately determines the precision and accuracy of artillery fire. In a study reported previously (1), both extreme heat and altitude were shown to decrease efficiency and accuracy of performance of certain mental functions known to be involved in FDC task performance. These findings have important military implications, since the impairments were produced by less severe environmental exposures than those to be found in many potential tactical operational areas of the world. This research is designed to relate the mental activities involved in military performance to the scientific psychological literature, using actual military tasks rather than laboratory analogs, but studying the psychological processes themselves as influenced by environmental stress.

Progress:

In the first study of this series (Study I) reported last year, significant impairments in performance of a number of FDC-type tasks were observed for altitude exposure (4000 m) and for heat (35°C, 88%RH), with altitude effects occurring sooner and showing subsequent recovery within the 7-hour exposure period involved. Heat impairments developed more slowly and showed little or no

recovery.

A second study (Study II) has been completed in FY77. This study used the same basic experimental design as Study I, but with the following major changes:

1. Training was increased from one week to two weeks to determine whether the significant training effects found in Study I might have been due to insufficient practice on the various tasks.

2. In Study I, subjects had no assigned tasks during on-duty hours when they were not receiving messages. In Study II, they were required to plot targets on maps and to determine the range between artillery battery locations and the targets, in between working on incoming communications (messages). This arrangement greatly increased the work load, since the subjects now had to perform continuously. It also provided a self-paced task for measuring the effects of the stressors, in addition to all of the previously used experimenter-paced tasks.

3. The heat conditions were made less severe, primarily by reducing the level of relative humidity. The conditions were 36.1$^{\circ}$C, 73%RH, resulting in an effective temperature of 89.5, as compared to an effective temperature of 92 used in Study I.

4. The meterological data recording task was not used.

The design of Study II involved four groups of six subjects each. They were all given two weeks of intensive training on three selected FDC-type tasks: (1) fire missions, involving reception and notation of range, elevation, and adjustment data relevant to hypothetical targets, and the calculation of site, a factor involved in vertical alignment of the guns requiring the use of a graphical site table, a slide rule device routinely used by FDC personnel; (2) reception, notation and decoding of map grid coordinates using a standard Army code wheel device; (3) reception, notation, and decoding of encoded military-type messages using a typical Army code book, and also plotted map targets and calculated the range from battery to target, as noted above.

All four tasks were then performed on four consecutive days under both control and stress conditions. Groups 1 and 3 experienced heat stress prior to altitude stress, while Groups 2 and 4 were exposed to the stressors in reverse order. All groups were tested the day before each stress exposure under control (normal)

conditions. The subjects were exposed to all conditions for seven hours each, and performed the FDC tasks during hours 1,3,5, and 7. The fourth hour was for lunch.

During the second and sixth hours of each day, the subjects were tested individually for about 20 minutes each on several "basic" psychological dimensions thought to be related to the military tasks they were performing. These were: (1) color discrimination, as involved in map reading and target plotting; (2) finger dexterity, as required in speed and accuracy of map pin placement; (3) ability to perform abstract tasks, as related to ability to orient to maps and to plotting targets.

Performance of the three FDC-type tasks was significantly affected by altitude exposure. Figure 1 shows the results of Study II compared to those of Study I, for all three tasks combined.

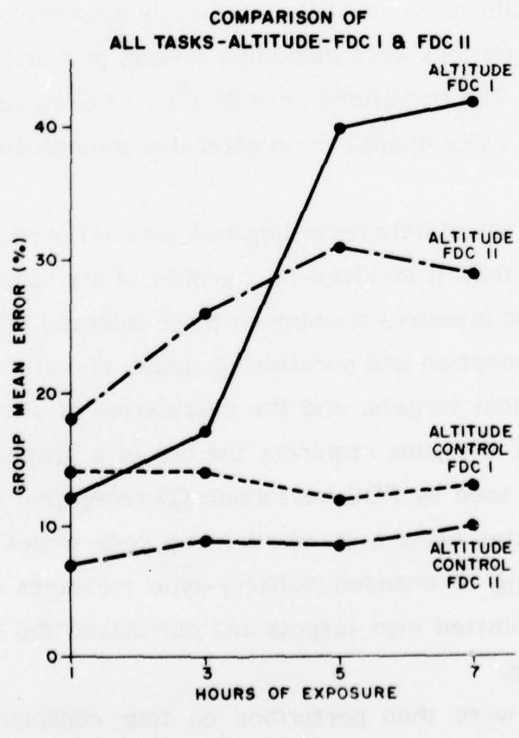


Figure 1. Effects of altitude on group mean errors for Study 1 compared to Study 2.

Control conditions in both studies showed no effects of fatigue over 7 hours, attesting to the high level of motivation of the subjects. Fewer errors in performance under control conditions were made in Study II than in Study I. This may be a function of the additional week of training afforded the subjects in Study II, or may reflect differences in ability levels between the subjects in the two studies.

The recovery in performance after five hours at altitude observed in Study I was not found in Study II, possibly because of the heavy work load imposed by the addition of the target plotting task. The difference in magnitude of altitude effect from Study I to Study II may be due to the increased work load or to differences in "types" of subjects in the two studies, since there were more "casualties" (subjects who had to be evacuated prior to completion of 7 hours exposure) in Study II than in Study I. Statistical analysis of each task separately yielded significant effects similar to those described above for the combined tasks.

Heat stress had lesser effects than altitude on performance, as shown in figure 2. The effects of heat became apparent only at hour 5, and increased thereafter to hour 7. The lesser effect of heat in Study II as compared to Study I may be due either to the less severe heat conditions used in Study II or to the increased length of the training period also used. However, since increased training did not appear to mitigate the effects of altitude, we are inclined to believe that the lesser heat effects on performance were due to the less stressful ambient temperature conditions.

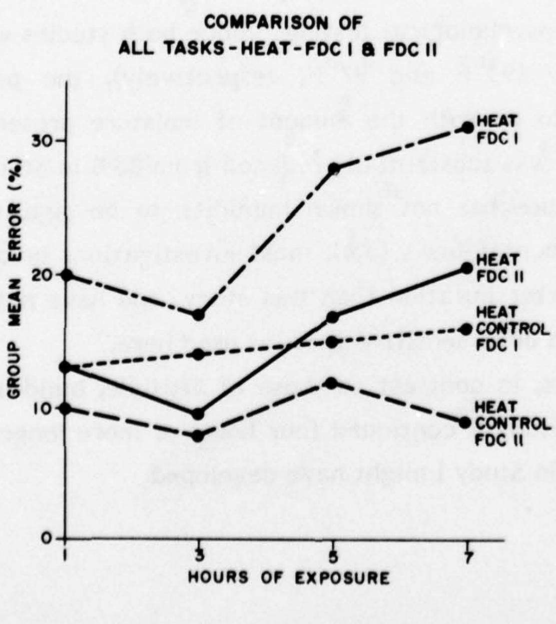


Figure 2. Effects of heat on group mean errors for Study I compared to Study 2.

The scientific literature (2) indicates that an effective temperature (ET) of $85^{o}$ appears to be a cut-off point above which decrements in performance occur during heat exposure. Our data indicate that this is not necessarily true, and that there is probably no absolute cut-off point delineating performance decrements. In our judgment, it is simplistic and even potentially risky to think in these terms. In point of fact, performance in the heat is clearly related not only to temperature and humidity, but also to length of exposure, work load, and activity levels of the subjects, as well as to numerous other conditions. Failure to consider all of these variables may result in faulty decisions leading to misuse of the capabilities of personnel in the heat. Although ET in itself was derived as an index of subjective comfort, and may well be one, it is valid only when considered as an average for large groups of people, and not as an index for specific individuals in specific situations. It was adapted for use as a behavioral predictor in the heat mainly because it appeared to be a convenient technique for integrating the combination of temperature and humidity. That it does not do so meaningfully with respect to performance appears to be substantiated by our research to date. While both Studies I and II used ET's considerably higher than the cut-off point noted above (92 for Study I and 89.5 for Study II), Study II showed much less effect of heat on performance, despite the substantially heavier work load imposed by the target plotting task and psychological testing. Since both studies were very similar in dry bulb temperature ($95^{o}$F and $97^{o}$F, respectively), the principal environmental differences had to do with the amount of moisture present in the air. In fact, relative humidity was substantially reduced from 88% in Study I to 73% in Study II. While the literature has not shown humidity to be significantly related to the performance of mental tasks (3,4), most investigations involving humidity effects have been of shorter duration than this study, and have not had as heavy or continuous work loads or as sensitive tasks as used here.

Heat effects, in contrast to those of altitude, build up slowly, and it would appear that had Study II continued four hours or more longer, decrements as large as those incurred in Study I might have developed.

Results of the target plotting performance are shown in Figure 3. It is clear that target plotting was significantly affected by both altitude and heat, not only in terms of number of targets attempted, but also in percentage of targets plotted correctly.

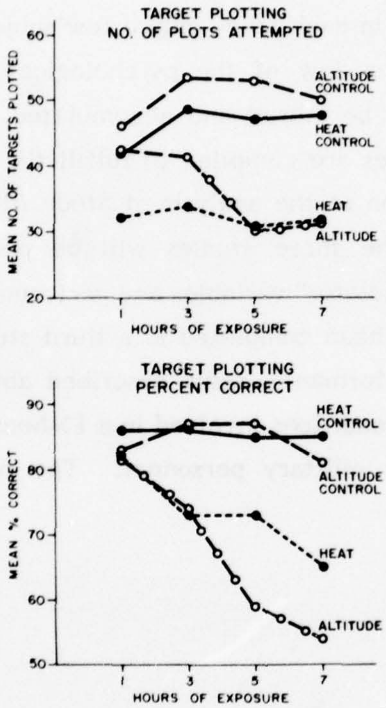


Figure 3. Effects of altitude and heat on group mean number of targets plotted, and on group mean of percent correct targets.

The psychological measures taken during the second and sixth hours of each day showed no significant changes due to altitude or heat exposures. The pin placement task, measuring manual dexterity, showed a very small decrement during the morning exposure to heat only. The map puzzle data were not usable because of a large practice effect, and most subjects continuted to improve their performance throughout the entire study. The color discrimination task showed no overall effects of environmental stress, but exhibited remarkable individual

difference patterns; i.e., some subjects improved under stress, some performed more poorly, and some did not change at all. This is typical of performance on virtually any task, but was particularly evident here. However, this kind of widely varying response to stress is precisely what we are interested in studying. A major problem, however, is that in each study only a few subjects are on the extremes of any distribution of even a few of the psychological and other measures used. Therefore, the data must be stored and accumulated, and can only be analyzed when enough extreme cases are compiled to fulfill the requirements of statistical testing. At the completion of the analysis of Study III (see below), the individual differences aspects of the three studies will be pooled and the relationships between the so-called "predictor" variables and performance will be analyzed.

Data collection has been completed in a third study (Study III) investigating the effects upon the performance tasks described above of environmental heat stress and the simulated conditions involved in a 15-hour flight such as would occur in rapid translocation of military personnel. The results are presently being analyzed.

Presentations:

None.

Publications:

None.

## LITERATURE CITED

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4. Fine, B. J., A. Cohen, and B. Crist. The effect of exposure to high humidity at high and moderate ambient temperature on complex mental performance. Psychol. Repts. 7:171-181, 1960.

(82012)

| RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY | | | | 1. AGENCY ACCESSION* | 2. DATE OF SUMMARY* | REPORT CONTROL SYMBOL |
|---|---|---|---|---|---|---|
| | | | | DA OB 6149 | 77 10 01 | DD-DR&E(AR)636 |
| 3. DATE PREV SUM'RY | 4. KIND OF SUMMARY | 5. SUMMARY SCTY* | 6. WORK SECURITY* | 7. REGRADING* | 8a. DISB'N INSTR'N | 8b. SPECIFIC DATA-CONTRACTOR ACCESS | 9. LEVEL OF SUM |
| 76 10 01 | D. Change | U | U | NA | NL | ☒ YES ☐ NO | A. WORK UNIT |

| 10. NO./CODES:* | PROGRAM ELEMENT | PROJECT NUMBER | TASK AREA NUMBER | WORK UNIT NUMBER |
|---|---|---|---|---|
| a. PRIMARY | 6.11.02.A | 3E161102BS08 | 00 | 012 |
| b. CONTRIBUTING | | | | |
| c. XXXXXXX | CARDS 114f | | | |

11. TITLE (Precede with Security Classification Code)*
(U)Assessment of the Impact of Environmental Stressors on Systemic Hypotension (22)

12. SCIENTIFIC AND TECHNOLOGICAL AREAS*
012900 Physiology; 012600 Pharmacology; 016200 Stress Physiology

| 13. START DATE | 14. ESTIMATED COMPLETION DATE | 15. FUNDING AGENCY | 16. PERFORMANCE METHOD |
|---|---|---|---|
| 76 10 | CONT | DA | C. In-House |

17. CONTRACT/GRANT
a. DATES/EFFECTIVE: EXPIRATION:
b. NUMBER:* NOT APPLICABLE
c. TYPE: d. AMOUNT:
e. KIND OF AWARD: f. CUM. AMT.

| 18. RESOURCES ESTIMATE | | a. PROFESSIONAL MAN YRS | b. FUNDS (In thousands) |
|---|---|---|---|
| FISCAL YEAR | PRECEDING 77 | 3. | 85 |
| | CURRENT 78 | 3.9 | 164.7 |

19. RESPONSIBLE DOD ORGANIZATION
NAME:* USA RSCH INST OF ENV MED
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TELEPHONE: 955-2811

20. PERFORMING ORGANIZATION
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ADDRESS:* Natick, MA 01760
PRINCIPAL INVESTIGATOR (Furnish SSAN if U.S. Academic Institution)
NAME:* JACKSON, Ronald E., MAJ, MC
TELEPHONE: 955-2813
SOCIAL SECURITY ACCOUNT NUMBER:
ASSOCIATE INVESTIGATORS
NAME: BERBERICH, Joel, CPT,MSC,Ph.D.
ROBERTS, Donald E., Ph.D.
NAME: JAEGER, James J., CPT, MSC,Ph.D. DA

21. GENERAL USE
Foreign Intelligence Not Considered

22. KEYWORDS (Precede EACH with Security Classification Code) (U)Altitude,(U)Hypoxia,(U)Heat,(U)Cold,(U)Disabilities, (S)Systemic Hypotension, (U)Treatment; (U) Hypothermia

23. TECHNICAL OBJECTIVE,* 24. APPROACH, 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)

23.(U)The phase of systemic hypotension (shock) which receives the most investigative effort is the normovolemic period following volume replacement. If preceded by sufficient stress during the hypotensive phase the normovolemic phase progresses to "irreversible shock" and death. Current military concepts limit the initial stress to primary wound trauma. The degree to which environmental stressors (altitude, cold, heat) interact with traumatic injury and induce or accelerate irreversible shock has not been explored. Trauma of a usual non-fatal nature may precipitate systemic hypotension given the environmental stressors under which combat troops fight and are evacuated. The purpose of this work unit is to expand our knowledge of the interaction of environmental stressors on the development and progression of shock.

24. (U)A hemorrhagic model of systemic hypotension will be developed and standardized in an animal model which will permit an investigation of the multitude of factors associated with "shock." The environmental stressors of altitude, cold, and heat will be applied to the animal model prior to and/or during hemorrhagic shock to determine their impact on the post-normovolemic phase. The information will be used in developing guidance for the prevention and treatment of shock in harsh environments.

25. (U)76 10 - 77 09 Literature survey has been completed and animal protocol for model preparation and evaluation will be initiated in FY 78.

*Available to contractors upon originator's approval.

DD FORM 1498, 1 MAR 68 — PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE. DD FORMS 1498A, 1 NOV 65 AND 1498-1, 1 MAR 68 (FOR ARMY USE) ARE OBSOLETE.

Program Element: 6.11.02.A DEFENSE RESEARCH SCIENCES, ARMY

Project: 3E161102BS08 Environmental Stress, Physical Fitness and Medical Factors in Military Performance

Work Unit: 012 Assessment of the Impact of Environmental Stressors on Systemic Hypotension

Study Title: The Effects of Systemic Hypotension and Hypothermia on the Cardiorespiratory Functions of the Swine.

Investigators: Donald E. Roberts, Ph.D. and Ronald E. Jackson, MAJ, MC

## Background:

Systemic hypotension (shock), whether hemorrhagic or neurogenic, is not an uncommon complication of combat or peacetime trauma. If promptly diagnosed and properly treated, the individual may be treated and returned to activity. If not treated, the individual may progress to a chronic hospitalization and/or death. Systemic hypotension may be complicated by existing environmental factors. High altitude operations place an individual in an hypoxic environment which may complicate the medical status of an individual with systematic hypotension. The peripheral vasodilation which accompanies the responses to a hot environment would be in opposition to the peripheral vasoconstriction necessary for the body's response to systemic hypotension. However, in cold environments, peripheral vasoconstriction may be potentiated by that which occurs as a result of shock and result in an increase in peripheral tissue cold injury. Also, decreased blood volume resulting from hemorrhage may result in an increased rate and depth of hypothermia. Initial efforts have been directed toward developing an appropriate animal shock model in which the effect of cold on the response to shock can be determined.

## Progress:

Review of the literature indicates that the animal of choice is the swine.

During the coming year preliminary work on the development of the animal model will proceed, and subsequently, the effects of hypothermia on systemic hypotension will be evaluated.

Presentations:

None

Publications:

None

(82013)

| RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY | | 1. AGENCY ACCESSION* | 2. DATE OF SUMMARY* | REPORT CONTROL SYMBOL |
|---|---|---|---|---|
| | | DA OB 6143 | 77 10 01 | DD-DR&E(AR)636 |

| 3. DATE PREV SUM'RY | 4. KIND OF SUMMARY | 5. SUMMARY SCTY* | 6. WORK SECURITY* | 7. REGRADING* | 8a. DISB'N INSTR'N | 8b. SPECIFIC DATA-CONTRACTOR ACCESS | 9. LEVEL OF SUM |
|---|---|---|---|---|---|---|---|
| 77 06 15 | D. Change | U | | NA | NL | [X] YES [ ] NO | A. WORK UNIT |

| 10. NO./CODES:* | PROGRAM ELEMENT | PROJECT NUMBER | TASK AREA NUMBER | WORK UNIT NUMBER |
|---|---|---|---|---|
| a. PRIMARY | 6.11.02.A | 3E161102BS08 | 00 | 013 |
| b. CONTRIBUTING | | | | |
| c. ~~XXXXXXX~~ | CARDS 114f | | | |

11. TITLE (Precede with Security Classification Code)*

(U) Models of Heat Disability: Predisposing Factors (22)

12. SCIENTIFIC AND TECHNOLOGICAL AREAS*

016200 Stress Physiology; 013400 Psychology; 003500 Clinical Medicine

| 13. START DATE | 14. ESTIMATED COMPLETION DATE | 15. FUNDING AGENCY | 16. PERFORMANCE METHOD |
|---|---|---|---|
| 76 10 | CONT | DA | C. In-House |

17. CONTRACT/GRANT

a. DATES/EFFECTIVE: EXPIRATION:

b. NUMBER:* NOT APPLICABLE

c. TYPE: d. AMOUNT:

e. KIND OF AWARD: f. CUM. AMT.

| 18. RESOURCES ESTIMATE | | a. PROFESSIONAL MAN YRS | b. FUNDS (In thousands) |
|---|---|---|---|
| FISCAL YEAR | PRECEDING 77 | 3.3 | 141 |
| | CURRENT 78 | 3.8 | 148.4 |

19. RESPONSIBLE DOD ORGANIZATION

NAME:* USA RSCH INST OF ENV MED

ADDRESS:* Natick, MA 01760

RESPONSIBLE INDIVIDUAL

NAME: DANGERFIELD, HARRY G., M.D., COL, MC

TELEPHONE: 955-2811

20. PERFORMING ORGANIZATION

NAME:* USA RSCH INST OF ENV MED

ADDRESS:* Natick, MA 01760

PRINCIPAL INVESTIGATOR (Furnish SSAN if U.S. Academic Institution)

NAME:* MAGER, Milton, Ph.D.

TELEPHONE: 955-2871

SOCIAL SECURITY ACCOUNT NUMBER:

ASSOCIATE INVESTIGATORS

NAME: HUBBARD, Roger, Ph.D.

NAME: FRANCESCONI, Ralph P., Ph.D. DA

21. GENERAL USE

Foreign Intelligence Not Considered

22. KEYWORDS (Precede EACH with Security Classification Code) (U)Rat Heatstroke Model; (U)Prehydration; (U)Heatstroke Prevention; (U)Heatstroke Treatment

23. TECHNICAL OBJECTIVE,* 24. APPROACH, 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)

23. (U)The use of model systems to study the effects of predisposing factors on the incidence and severity of disabilities, injuries and performance decrements associated with military operations in the heat.

24. (U)Models will be used to document and elucidate the role of obesity, dehydration, alcohol, drugs etc. in predisposing animals to heat illness.

25. (U)76 10 - 77 09 Previous results from this laboratory have established dose-response curves for heat-induced mortality based on an integrated measurement of the time and intensity of body heating, i.e. degree-minutes above a baseline body core temperature of 40.4°C. For example, 49.5 degree-minutes above baseline is equivalent to an LD 75 for heat. On the assumption that dehydration may predispose animals to heatstroke shock and death, adult rats received intravenously 3% of their body weight as either 5% dextrose or 0.9% saline in three 1% infusions: (1) preexposure to 41.5°C ambient, (2) at a body core temperature of 40.4°C and (3) when thermal exposure reached 50 degree-min. The total thermal stress was equivalent to an LD 95 (61.2 degree-min.) and the average maximum core temperature was 41.8 $\pm$ 0.4°C. The 24 hour survival rate was 96% for dextrose and 88% for saline infused animals. These results suggest that prehydration and adequate volume replacement during heat exposure can forestall the lethal effects of acute hyperthermia in the rat.

*Available to contractors upon originator's approval

DD FORM 1 MAR 68 1498 PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE. DD FORMS 1498A, 1 NOV 65 AND 1498-1, 1 MAR 68 (FOR ARMY USE) ARE OBSOLETE



* U.S. GPO: 1974-540-843/8691

| | |
|---|---|
| Program Element: | 6.11.02A DEFENSE RESEARCH SCIENCES, ARMY |
| Project: | 3E161102BS08 Environmental Stress, Physical Fitness and Medical Factors in Military Performance |
| Work Unit: | 013 Models of Heat Disabilities: Predisposing Factors |
| Study Title: | The Use of Prehydration and Volume Replacement to Prevent Acute Heatstroke Mortality |
| Investigator: | Roger W. Hubbard, Ph.D. |

Background:

A peripheral concept of heatstroke mortality suggests primary failure in the circulatory system followed by shock (1-4). Shock, from whatever cause, is a failure of adequate perfusion of vital organs. Only three hemodynamic deficiencies exist regardless of the etiology: (a) volume deficit, (b) cardiac deficit, or (c) peripheral pooling (5). Volume replacement is probably only beneficial in the first. The metabolic defect in shock is a hypoxic acidosis resulting from inadequate tissue perfusion. Tissue anaerobiosis results in the accumulation of lactic acid. Arterial blood lactate levels have prognostic significance and as such are the most reliable indicator of irreversible shock in human beings (5). Arterial pH is low and serum lactic acid is high in heatstroke (6,7). In studies on progressive hyperthermia in dogs with body temperatures ranging to 43°C (8), arterial $PO_2$ increased without regard to temperatures throughout while increased net production of lactate occurred only in animals with body temperatures greater than 41°C. In a recent review, Knochel (9) has reemphasized the concept that hard work in a hot environment may lead to a serious deficit of effective arterial volume and profound shock would occur were it not for intense splanchnic vasoconstriction. This effect could be missed in an isolated, perfused organ system model.

The diminution of cutaneous blood flow during exhaustive exercise in the heat jeopardizes the ability to dissipate heat from the skin. For example, just prior to exhaustion, running rats display a drastic drop in tail temperature that coincides with an explosive rise in core temperature (10). In a recent study by Kozlowski and Domaniecki (11), the thermoregulatory ability of two groups of men with high and low cardiac capacity ($VO_2$ max) were compared during long term physical efforts.

No differences were found between either group during exercise with a relative load of 30-50% of maximum. However, after 40-60 minutes of work at 65% $VO_2$ max, the rectal temperature of the group with lower aerobic capacity increased sharply and was significantly greater than the relatively plateaued rectal temperature of the group with the higher aerobic capacity. The author's discussion of these results had many features reminiscent of Adolph's original hypothesis regarding the cause of heatstroke (1). The time factors (40-90 min) of this occurrence were also similar to our rat results (10) and indicates the general nature of this phenomenon in animals and in trained and untrained, acclimatized and non-acclimatized humans (11,12). In this regard, we have recently demonstrated that work-related factors contribute to an increased rate of heatstroke death in rats at low thermal loads (13). These results suggest that the cardiovascular response to work predisposes to heatstroke shock. Since a normal functioning cardiovascular system is a prerequisite for effective heat dissipation, the prevalence of heatstroke in the older population during heat waves is easily understood (9). Dehydration, which may accompany heatstroke, also disrupts heat dissipation. During exercise in the heat with water restriction, it was found that the more severe the dehydration, the higher were the body temperatures and heart rates (14). This background information has given rise to the simple hypothesis that prehydration and volume replacement might prevent or forestall acute heatstroke mortality in a toxicologically designed experimental paradigm.

**Progress:**

Previous results from this laboratory have established dose-response curves for heat-induced mortality based on the time and intensity of body heating, i.e. thermal area curve, in degree-min. above a baseline core temperature of 40.4°C. Based on data from 112 rats restrained at 41.5°C, LD 25, 50, and 75 were calculated at 30.1, 39.3 and 49.5 degree-min., respectively. To ascertain whether prehydration and volume replacement will prevent heatstroke, a group of rats (n=48) received intravenously 3% of their body weight as either 5% dextrose or 0.9% saline in three 1% infusions: (1) pre-exposure to 41.5°C ambient, (2) at a core temperature of 40.4°C and (3) when thermal area was 50 degree-min. The 24 hour

survival rate was 96% for dextrose and 88% for saline infused animals. The dextrose groups' thermal area was 61.2 $\pm$ 8.4 degree-min. (LD 95) and was characterized by a: wt. loss 2.0 $\pm$ 1%; HCT, 46.2 $\pm$ 3.3; plasma $Na^+$ and $K^+$ 153.0 $\pm$ 4.4 and 6.7 $\pm$ 1.2 meq/L; heating rate, 0.04 $\pm$ 0.02 C/min; cooling rate at 26°C, -5.0 $\pm$ 1.5 C/hr. Plasma enzyme analysis indicated liver damage in both groups of rats.

These results suggest that prehydration and adequate plasma volume replacement during heat exposure can forestall acute lethal hyperthermia. Future research will be directed toward elucidating the biophysical, physiological and biochemical basis for these results.

Presentations:

Hubbard, R., C. Kelly, and R. Criss. The use of prehydration and volume replacement to prevent acute heatstroke mortality. APS Annual Fall Meeting, Anaheim, California, October 1976.

Publications:

1. Hubbard, R. W., W. D. Bowers, Jr. and M. Mager. A study of physiological, pathological and biochemical changes in rats with heat-and/or work-induced disorders. Israel J. Med. Sci. 12:844-886, 1976.

2. Hubbard, R. W., W. T. Matthew, J. D. Linduska, F. C. Curtis, W. D. Bowers, I. Leav, and M. Mager. The laboratory rat as a model for hyperthermic syndromes in humans. Am. J. Physiol. 231:1119-1123, 1976.

3. Hubbard, R. W., W. D. Bowers, W. T. Matthew, F. C. Curtis, R. E. L. Criss, G. M. Sheldon, and J. W. Ratteree. Rat model of acute heatstroke mortality. J. Appl. Physiol.: Respirat. Environ. Exercise Physiol. 42:809-816, 1977.

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(83041)

**RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY**

| 1. AGENCY ACCESSION* | 2. DATE OF SUMMARY* | REPORT CONTROL SYMBOL |
|---|---|---|
| DA OB 6141 | 77 10 01 | DD-DR&E(AR)636 |

| 3. DATE PREV SUM'RY | 4. KIND OF SUMMARY | 5. SUMMARY SCTY* | 6. WORK SECURITY* | 7. REGRADING* | 8a. DISB'N INSTR'N | 8b. SPECIFIC DATA-CONTRACTOR ACCESS | 9. LEVEL OF SUM |
|---|---|---|---|---|---|---|---|
| 76 10 01 | D. Change | U | U | NA | NL | ☒ YES ☐ NO | A. WORK UNIT |

| 10. NO./CODES:* | PROGRAM ELEMENT | PROJECT NUMBER | TASK AREA NUMBER | WORK UNIT NUMBER |
|---|---|---|---|---|
| a. PRIMARY | 6.27.77.A | 3E762777A845 | 00 | 041 |
| b. CONTRIBUTING | | | | |
| c. XXXXXXXX | CARDS 114f | | | |

11. TITLE (Precede with Security Classification Code)*

(U)Prophylaxis of Cold Injury and Cold-Induced Manual Performance Decrement (22)

12. SCIENTIFIC AND TECHNOLOGICAL AREAS* 002300 Biochemistry; 002600 Biology; 003500 Clinical Medicine; 005900 Environmental Biology; 012600 Pharmacology; 012900 Physiology

| 13. START DATE | 14. ESTIMATED COMPLETION DATE | 15. FUNDING AGENCY | 16. PERFORMANCE METHOD |
|---|---|---|---|
| 76 10 | CONT | DA | C. In-House |

17. CONTRACT/GRANT

a. DATES/EFFECTIVE: EXPIRATION:

b. NUMBER:* NOT APPLICABLE

c. TYPE: d. AMOUNT:

e. KIND OF AWARD: f. CUM. AMT.

| 18. RESOURCES ESTIMATE | | a. PROFESSIONAL MAN YRS | b. FUNDS (In thousands) |
|---|---|---|---|
| FISCAL YEAR | PRECEDING 77 | 3.6 | 109 |
| | CURRENT 78 | 3.8 | 82.6 |

19. RESPONSIBLE DOD ORGANIZATION

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TELEPHONE: 955-2813

SOCIAL SECURITY ACCOUNT NUMBER:

ASSOCIATE INVESTIGATORS

NAME: JAEGER, James J., CPT, MSC

SAMPSON, James B., Ph.D.

NAME: McCARROLL, James E., MAJ, MSC DA

21. GENERAL USE

Foreign Intelligence Not Considered

22. KEYWORDS (Precede EACH with Security Classification Code) (U)Cold Injury Prevention; (U) Peripheral Blood Flow; (U)Facial Rewarming;(U)Cold Induced Vasodilation;(U)Biofeedback;(U)Reactive Hyperemia

23. TECHNICAL OBJECTIVE,* 24. APPROACH, 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)

23. (U)The relative loss of fighting manpower was greater for cold injury in the Korean conflict than for malaria in the Vietnam conflict. Five integrated strategies are proposed by this work unit which may logically protect soldiers from the cold and improve manual performance: reactive hyperemia (tourniquot release, forced exercise, facial warming, psychological conditioning, and pretreatment with Vitamin C.

24. (U)The effect of isometric and isotonic exercises on skin temperature and other physiologic parameters in the cold will be used to study the effect on peripheral skin temperature. Twenty-four subjects will be tested in a cold environmental chamber $-5^{\circ}C$ wearing full arctic uniforms, and having one hand exposed. Volunteers will be tested on high and low of their maximum voluntary contraction rate on isometric and isotonic hand exercising hand apparatus. Responses under different temperatures will be recorded. Finger blood flow will be evaluated with impedance plethysmography and mercury strain gauge techniques. Hand temperatures in different environmental chambers will be evaluated after utilizing a radiant belt heating of the forehead for various time intervals. The ability of the individual to vasodilate in response to heating the forehead will be studied.

25. (U)76 10 - 77 09 Data collection has been completed on exercise as a means of hand rewarming and has been initiated on the evaluation of facial warming and conditional methods for inducing peripheral vasodilation. Data collection on hand rewarming by arm exercise has been completed and data analysis is on-going.

*Available to contractors upon originator's approval

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|---|---|
| Program Element: | 6.27.77.A. ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE. |
| Project: | 3E762777AB45 Environmental Stress, Physical Fitness and Medical Factors in Military Performance. |
| Work Unit: | 041 Prophylaxis of Cold Injury and Cold-Induced Manual Performance Decrement |
| Study Title: | Hyperemia as a Method of Rewarming Extremities |
| Investigators: | James, J. Jaeger, CPT, MSC and Donald E. Roberts, Ph.D. |

Background:

While vigorous exercise remains the best way for an individual to rewarm hands which have become cooled during exposure to cold, there are situations where exercise is not possible or practical. Soldiers who are attempting to maintain concealment or who are confined in a small space would benefit from a method of hand warming which does not require much movement or changes in position. Reactive hyperemia in the hand can be produced by an individual equipped with a pneumatic cuff or a simple tourniquet. If a second individual is present, arterial occlusion can be achieved by applying pressure at appropriate anatomical locations. Experiments on humans are needed to evaluate the net effect of producing reactive hyperemia on hand and finger temperatures.

The characteristics of reactive hyperemia in the human forearm, hand and finger have been described in detail (1,6,7,9). With release of arterial occlusion, blood flow to ischemic tissue increases rapidly, reaching a peak flow within 30 seconds. This increased blood flow to both skin and muscle decreases thereafter, returning to pre-occlusion levels within 3 to 15 minutes. The increased local blood flow is described as a "blood debt repayment" which can be expressed as a fraction of the product of pre-occlusion blood flow and the duration of occlusion (8). Reactive hyperemia of the human limb is quite variable, ranging from 50 to 200 percent of the calculated blood "debt" (7). Factors which are known to affect magnitude of the hyperemic response are: the age of the subject, peripheral vascular tone, duration and site of occlusion, and the thermal environment and tissue temperature of the occluded segment (1,4,6,7,9).

Mechanisms producing reactive hyperemia are capable of overcoming the vasoconstriction induced by central or peripheral cooling (2,3,4). However, the excess blood flow under these conditions is less than that observed in the absence of increased peripheral vascular tone. The value of reactive hyperemia for an individual in a vasoconstricted state due to cold exposure can be assessed by a comparison of skin temperature before, during and after the occlusion of blood flow. There is no data of this type available; however, two separate studies can be compared to provide some information on this point. Abramson et al. (1) reported that during hand immersion in a 5°C bath, hand temperatures decreased 3.8°C during a 15 minute period of arterial occlusion. Skin temperatures postocclusion were not reported. However, it can be inferred from this data that occlusion for 2 minutes or less should cause a much smaller decrease in skin temperature, probably on the order of 1°C. Little et al. (5) reported a 1.5 to 4.0°C increase in finger temperature following release of a 2 minute arterial occlusion on hands immersed in a 4°C water bath. Although skin temperatures during occlusion were not reported, it was noted that the post-occlusion increase in skin temperature was greater than that resulting from spontaneous cold-induced vasodilation (CIVD).

The data from these experiments indicate that reactive hyperemia can produce transient increases in blood flow and skin temperature in cooled extremities. Thus, reactive hyperemia may be useful as a means of preventing or delaying cold injury to the hands in situations where exercise is not practical.

**Progress:**

This study was designed to evaluate the effectiveness of reactive hyperemia in warming extremities in terms of a cooling hand model. Sufficient data on normal human hand cooling characteristics and their reliability must be gathered before the effectiveness of any experimental intervention can be evaluated. Consequently, execution of the experiments to evaluate reactive hyperemia as a rewarming technique will not begin until a cooling hand model has been developed.

Data on normal hand cooling characteristic will be obtained and analyzed. Following analysis and stability of the hand cooling model, work on reactive hyperemia will be instituted.

Presentations:

None

Publications:

None

## LITERATURE CITED


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|---|---|
| Program Element: | 6.27.77.A. ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE. |
| Project: | 3E762777AB45 Environmental Stress, Physical Fitness and Medical Factors in Military Performance. |
| Work Unit: | 041 Prophylaxis of Cold Injury and Cold-Induced Manual Performance Decrement |
| Study Title: | Hand Rewarming by Means of Arm Exercise |
| Investigator: | James E. McCarroll, MAJ, MSC |

Background:

Inactivity puts a soldier at high risk for cold injury when exposed to low environmental temperatures for long periods of time. Attempts have been made to control skin temperature by hypnotic suggestion (2,5) and biofeedback (4). Temperature changes have been in the direction of modest increases at best ($2^{\circ}$ - $3^{\circ}$C) and have been unreliable both within and between subjects. Lowering the ambient temperature from room temperature ($22.5^{\circ}$C) to a slightly cool temperature ($19.5^{\circ}$C) decreased the ability of subjects to increase their skin temperature (7). When warmly dressed subjects were placed in a cold room ($7^{\circ}$C) it was found that some subjects could successfully rewarm and some could not (6). An increase of $0.3^{\circ}$C was called successful. The average increase was $1.54^{\circ}$C. Since the subjects were gloved their hand skin temperature was not cold (average at start was $25.33^{\circ}$C, the average at the end was $25.49^{\circ}$C).

Cold environmental temperatures produce peripheral vasoconstriction which tends to prevent heat loss from the extremities and protects the core from cooling for a longer time. It should be difficult to override the body's natural protective mechanism which serves to protect the central region. The mechanism of cold-induced vasodilation (CIVD) is the body's natural mechanism to periodically increase blood flow to the extremities and protect the periphery against cooling and later frostbite. The mechanism of CIVD is unknown, but the process consists of a periodic release of blood which serve to rewarm the periphery. An analogy may be made to a hydraulic system.

A study was performed to determine the reliability of CIVD on repeated

exposures (1). Data indicate that comparisons of skin temperature changes in a cold environment may be made reliably by using subjects as their own control.

In view of the modest, unreliable skin temperature changes that have been achieved with cognitive methods, it was decided to attempt the use of somatic techniques to try to effect increases in skin temperature in the cold. Outside of whole body exercise, it was felt that vigorous arm exercise would have the best potential effect due to increased requirements for muscle blood flow and associated vasodilation. Isometric and isotonic arm exercises at 50 percent of maximum voluntary contraction (MVC) were selected.

Progress:

Twelve subjects were tested with isometric and isotonic exercises (6 each) in a cold and in a normal temperature room. The exercises were performed on a stationary handgrip resting on a table top in front of the subject with the arm at an angle of $135^{\circ}$ with the table surface. Subjects were dressed in a full arctic uniform except for the right hand which was exposed. The tests were conducted in a cold room at a temperature of $0^{\circ}C$. A baseline control day allowed the normal cooling and rewarming pattern of the subject to be observed. This was followed by a second day in which 5 minute exercise bouts of rhythmic exercise (3 seconds on, 3 seconds off) were introduced at irregular times in an attempt to induce peripheral rewarming. A second day of the same type of exercise was performed in a normal temperature room. Each subject was exposed at the same time of day to prevent confounding by circadian variations in body temperatures. Subjects were removed from the cold if skin temperature fell below $4.5^{\circ}C$. Skin temperature was measured by means of 16 point thermocouple harness with copper constantan thermocouples taped to the skin. Rectal temperature was measured with a rectal probe. Skin and rectal temperature were recorded each minute in a PDP 11/40 computer. Skin temperatures on the exposed hand were measured on the thumb, middle and little fingers. Data analysis has just begun and only preliminary findings can be reported. The mean duration of exposure on the exercise day was significantly longer than that on the baseline day (172 min for exercise and 134 min for baseline day $t = 4.384$, $p$ .01 ). Of the 12 subjects, 8 showed CIVD activity on

at least one digit during the baseline period. Four subjects showed no CIVD activity. One subject was removed from the cold room when his skin temperature decreased to 4.9°C. For the 4 subjects who showed no CIVD on baseline day, on the exercise day large magnitude temperature increases were noted. The interaction of the cold induced vasodilation phenomenon with exercise-induced rewarming and the effects of isotonic and isometric exercises upon heat production are currently being analyzed.

Presentations:

None

Publications:

None

## LITERATURE CITED

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| Program Element: | 6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE |
| Project: | 3E762777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance |
| Work Unit: | 041 Prophylaxis of Cold Injury and Cold-Induced Manual Performance Decrement |
| Study Title: | Conditional Methods for Inducing Peripheral Vasodilatation in the Cold |
| Investigator: | James B. Sampson, Ph.D. |

Background:

Peripheral vasodilatation in the cold is thought to be an important defense in resistance to frostbite (1). Cold-induced vasodilatation (CIVD) is a natural rewarming which occurs in most people upon exposure to cold (less than 10°C), but its occurrence is unpredictable and its mechanism of action is unknown (2). Many people suffer from cold hypersensitivity through lack of CIVD or inherent constitutional factors.

The treatment of cold hypersensitive individuals has been attempted and claimed to be a promising therapy (3), but methodological difficulties remain to be resolved. Classical (Pavlovian) conditioning of vasodilatation is known to be more difficult to establish and more easily extinguished than a vasoconstrictive response (4). It is planned to test the feasibility of establishing a conditioned vascular response (vasodilatation) to cold in both normal and cold hypersensitive individuals.

Progress:

A table top hand cooling box will be used to cool the hand of the subject so the effect of cold can be localized to the hand and an electrically heated glove will be used as the source of heat to which the conditional response will be attached. Cold hypersensitive subjects will be compared to normal subjects in order to determine if there is a difference between the 2 types in the pre-test cooling, ease of conditioning or extinction of the conditioned response. Literature survey has been completed, and data collection has commenced.

Presentations:

None

Publications:

None

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3. Marshall, H. C. and Gregory, R. T. Cold hypersensitivity: a simple method for its reduction. Archives of Physical Medicine and Rehabilitation 55:119-124, 1974.

4. Figar, S. Conditional circulatory responses in man and animals. In: W.F. Hamilton and P. Dow (Eds.). Handbook of Physiology: Circulation, Volume III, Washington, DC: American Physiological Society, pp. 1991-2036, 1965.

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|---|---|
| Program Element: | 6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE. |
| Project: | 3E762777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance |
| Work Unit: | 041 Prophylaxis of Cold Injury and Cold-Induced Manual Performance Decrement |
| Study Title: | Evaluation of Facial Warming to Improve Peripheral Cold Response |
| Investigator: | Joel J. Berberich, CPT, MSC, Ph.D. |

## Background:

Historically the loss of fighting manpower and the strain placed on military and medical logistics and support due to cold injury have been significant. The military significance of optimizing performance in cold weather is manifest. Accordingly, such strategies that provide additional heat to the extremities would be useful accomplishments.

The technique of inducing indirect peripheral vasodilation by warming the face has been described by Bader and Macht (1,2). These investigators found facial warming to be far more effective than chest or limb warming in inducing vasodilation of the hands. A rise in hand skin temperature of 10°C was the average gain when subjects were exposed to ambient temperature of 15°C. Facial warming essentially restored hand temperature to normal levels. In this study an infrared lamp (250 W) was used to warm the entire face so as to maintain a skin temperature of 42°C for an 80-90 minute period. Unfortunately, this study was restricted to only two subjects exposed to unrealistically warm environments.

Additional evidence supports the concept of specific physiological responses to facial warming. Thermal irradiation of the face has elicited far greater physiological thermoregulatory responses for the cat (3) and for man (4,5) when directly compared to irradiation of other parts of the body. Similarly, greater sensitivity to facial irradiation was found for psychophysiological warmth perception in man (6).

We sought to determine whether or not facial warming elicited hand warming in cold environments. It was decided at the outset to limit facial warming to the forehead since the heat input required would be minimized and the possible utility for the soldier maximized.

Progress:

Ten volunteers were exposed to +25°C, 0°C, and -25°C environments dressed in appropriate clothing. For cold exposures, their hands were either bare (0°C) or lightly gloved (-25°C). The subjects were exposed twice to each environment: once with and once without facial warming. The center of the forehead was warmed to 42°C for 30-45 minutes during the exposure with an incandescent light. Rectal temperature and 34 skin temperatures were continuously measured using copper-constantan thermocouples (4 each hand, 4 each foot, 8 trunk and activity sites for mean temperature and 8 facial sites). Heart rate was also measured. The hypothesis was tested by comparing extremity (hand and foot) temperatures for each subject for the facial warming and non-facial warming exposures.

Only preliminary results are available at this time for the entire period of facial warming and hand averages (Table 1).

TABLE 1
AREA UNDER TEMPERATURE CURVE
AVERAGE OF 3 FINGERS

| | Control | Facial Warming | Control | Facial Warming |
|---|---|---|---|---|
| | 1-44 Mins. | 1-44 Mins. | 45-105 Mins. | 45-105 Mins. |
| Right finger average | 925 $\pm$ 49 | 964 $\pm$ 46 | 665 $\pm$ 30 | 694 $\pm$ 39 |
| Left Finger average | 948 $\pm$ 38 | 949 $\pm$ 52 | 682 $\pm$ 22 | 705 $\pm$ 30 |

The average of three finger temperatures is expressed as the area under a curve of temperature against time for both hands. Areas under the curve are

compared for minutes 1-44 and 45-105 of exposure to $0^{o}C$. The hands were bare from minutes 15-105; the facial warming extended from 45-90 minutes. Values are mean $\pm$ SEM for 9 subjects.

The data do not support a marked hand warming effect response to facial warming. The area under the temperature-time curve for 45-105 minutes was not significantly different for the facial warming and control groups. Although not shown, the data indicated limited improvement due to facial warming was found when shorter time intervals were compared for the two groups, especially the time intervals after prolonged facial warming (e.g., 75-80 min, 80-85 min, etc.).

<u>Presentations:</u>

None

<u>Publications:</u>

None

LITERATURE CITED

1. Bader, M. E. and M. B. Macht. Indirect peripheral vasodilation produced by the warming of various body areas. J. Appl. Physiol, 1:215-225, 1948.

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3. Kenshalo, D. R., D. G. Duncan, and C. Weymark. Thresholds for thermal stimulation of the inner thigh, footpad, and face of cats. J. Comp. Physiol.Psychol. 63:133-138, 1967.

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6. Stevans, J. C. and L. E. Marks. Spatial summation and the dynamics of warmth sensation. Percept. Psychophys. 9:391-398, '1.

(83042)

| RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY | | | | 1. AGENCY ACCESSION* | 2. DATE OF SUMMARY* | REPORT CONTROL SYMBOL |
|---|---|---|---|---|---|---|
| | | | | DA OB 6144 | 77 10 01 | DD-DR&E(AR)636 |

| 3. DATE PREV SUM'RY | 4. KIND OF SUMMARY | 5. SUMMARY SCTY* | 6. WORK SECURITY* | 7. REGRADING* | 8a. DISB'N INSTR'N | 8b. SPECIFIC DATA-CONTRACTOR ACCESS | 9. LEVEL OF SUM |
|---|---|---|---|---|---|---|---|
| 77 06 15 | D. Change | U | U | NA | NL | [X] YES [ ] NO | A. WORK UNIT |

| 10. NO./CODES:* | PROGRAM ELEMENT | PROJECT NUMBER | TASK AREA NUMBER | WORK UNIT NUMBER |
|---|---|---|---|---|
| a. PRIMARY | 6.27.77.A | 3E762777A845 | 00 | 042 |
| b. CONTRIBUTING | | | | |
| c. XXXXXXXX | CARDS 114f | | | |

11. TITLE (Precede with Security Classification Code)*

(U) Models of Heat Disabilities: Treatment and Diagnosis (22)

12. SCIENTIFIC AND TECHNOLOGICAL AREAS*

005900 Environmental Biology; 003500 Clinical Medicine

| 13. START DATE | 14. ESTIMATED COMPLETION DATE | 15. FUNDING AGENCY | 16. PERFORMANCE METHOD |
|---|---|---|---|
| 76 10 | CONT | DA | C. In-House |

17. CONTRACT/GRANT

a. DATES/EFFECTIVE: EXPIRATION:

b. NUMBER:* NOT APPLICABLE

c. TYPE: d. AMOUNT:

e. KIND OF AWARD: f. CUM. AMT.

| 18. RESOURCES ESTIMATE | | a. PROFESSIONAL MAN YRS | b. FUNDS (In thousands) |
|---|---|---|---|
| FISCAL YEAR | PRECEDING 77 | 5.2 | 200 |
| | CURRENT 78 | 6.5 | 208.6 |

19. RESPONSIBLE DOD ORGANIZATION

NAME:* USA RSCH INST OF ENV MED

ADDRESS:* Natick, MA 01760

RESPONSIBLE INDIVIDUAL

NAME: DANGERFIELD, HARRY G., M.D., COL, MC

TELEPHONE: 955-2811

21. GENERAL USE

Foreign Intelligence Not Considered

20. PERFORMING ORGANIZATION

NAME:* USA RSCH INST OF ENV MED

ADDRESS:* Natick, MA 01760

PRINCIPAL INVESTIGATOR (Furnish SSAN if U.S. Academic Institution)

NAME:* MAGER, Milton, Ph.D.

TELEPHONE: 955-2871

SOCIAL SECURITY ACCOUNT NUMBER:

ASSOCIATE INVESTIGATORS

NAME: HUBBARD, Roger, Ph.D.

NAME: FRANCESCONI, Ralph P., Ph.D. DA

22. KEYWORDS (Precede EACH with Security Classification Code) (U)Heatstroke Diagnosis;(U)Heatstroke prognosis;(U)Rat Heatstroke Model;(U)Dog Heatstroke Model;(U)Peritoneal Dialysis

23. TECHNICAL OBJECTIVE.* 24. APPROACH, 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)

23.(U)The use of model systems to develop new or modified forms of treatments or diagnosis for the various disabilities, injuries and performance decrements associated with military operations in the heat.

24. (U)A variety of agents will be evaluated for their efficacy in reducing core temperature, decreasing the pathological effects of hyperthermia, increasing performance, or alleviating the symptomatology of heat illness among humans or animals acutely exposed to high environmental temperatures or work regimens. Additionally, a variety of clinical and physiological parameters will be evaluated for their usefulness in the early diagnosis of heat illnesses, and to characterize in animals and humans those who have experienced or are susceptible to heat related injury.

25. (U) 76 10 - 77 09 Results from a rat heatstroke model demonstrated that both mortality and release of serum transaminases (SGPT and SGOT) are a function of the time and/or intensity of body heating. New data revealed: a) Fractional increases in hyperthermia are associated with exponential increases in SGPT, SGOT but not creatine phosphokinase (CPK); b) The pattern in enzyme activity of SGPT, SGOT and CPK can distinguish between work without hyperthermia, work with hyperthermia and hyperthermia alone; c) Dose-response curves suggest that working untrained rats to exhaustion lowers the threshold for both heatstroke mortality and cellular injury compared to the sedentary-heated condition; d) Rapid change in key enzymes (i.e. SGPT, SGOT) and electrolytes (serum $K^+$) are grave prognostic indicators. Studies on an anesthetized dog heatstroke model have led to the characterization of the pathophysiological events prior to and immediately following heatstroke, as well as the development of the use of peritoneal dialysis for the rapid cooling of these animals. This cooling procedure has increased survival rates from 25% to 71% in comparison to conventional techniques.

*Available to contractors upon originator's approval.

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| Program Element: | 6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE |
| Project: | 3E762777AB45 Environmental Stress, Physical Fitness and Medical Factors in Military Performance |
| Work Unit: | 042 Models of Heat Disabilities: Treatment and Diagnosis |
| Study Title: | Studies on Anesthetized Dog Heatstroke Model |
| Investigators: | Gaither D. Bynum, MAJ, MC, John Patton, CPT MSC, Wilbert D. Bowers, Ph.D., Irwin Leav, D.V.M., Jerry M. Brown, MAJ, MSC, Murray P. Hamlet, D.V.M. and David Dubose |

## Background:

Heatstroke is one of the oldest recorded diseases. Expanding upon and paraphrasing an excellent historical review by Eichler et al. (1), Biblical references to heatstroke deaths are found in the Book of Judah (Ch. 8, v. 2,3) and the Second Book of Kings (Ch. 4). In 24 B.C., Aelius Gallus led a military expedition to Arabia which was decimated by heatstroke, a "...malady which proved to be unlike any of the common complaints, but attacked the head and caused it to become parched, killing forthwith most of those who were attacked" (2). Heatstroke was recorded in epidemic proportions in Rome by Baglivi in 1694 (3). During a heatwave in Peking in 1743, an estimated 11,000 people died of heatstroke (4). More recent documentation of heatstroke is associated with mass migration such as military expeditions (5) and the 1959-60 pilgrimages to Mecca (6), or in mining operations (7). Lancisi of Italy was the first to associate high humidity with heatstroke in 1789 (3). In the 19th century a series of observations by English and American physicians further defined heatstroke and established the primary method of treatment which is still in use today: Jay Watts, Jr., noted elevated body temperatures with heatstroke (8); Coates was the first to externally cool heatstroke victims (9); in 1859 Levick suggested that lack of acclimatization played a significant role in heatstroke (4); and Andral and, later, Osler initially described the autopsy findings in heatstroke; petechiae, nonclotted blood in the vascular bed and venous engorgement (3).

In a military environment heat illnesses are a common and limiting factor of troop performance. Heatstroke, the most severe of the heat illnesses, has compromised military campaigns for at least 2000 years (2) and currently has an estimated incidence of 2% to 9% among healthy young men engaged in Military combat or training exercises (5,12,13). In the past, insightful and in depth definitions of the precipitating thermal environmental factors of heatstroke (5,14,15) have been generated. However, the basic treatments for heat illness remain unchanged after 120 years (9), mortality rates remain from 25 to 50% (13,20), and the pathophysiology of the disease remains without description or real understanding. Because of the lethality of the disease the data necessary to describe and evaluate the pathophysiology involved can be derived only from animal models.

The history of the use of animal heatstroke as a model for describing the pathophyisology and therapy for human heatstroke is both long and controversial. Bernard in 1858 and Woods in 1872 are reported to have produced and described heatstroke in various mammals and birds (21). In 1927, Hall and Wakefield described gross, microscopic and biochemical changes in the first major animal heatstroke study (21). In 1927, Hall and Wakefield described gross, microscopic and biochemical changes in the first major animal heatstroke study (21). This was the first dog heatstroke model and also the first study to question the general applicability of animal heatstroke models to man. A miscellaneous assortment of pathology heat injury studies were performed on dogs, mice and rats between 1927 and 1935 (22,23,24,25). These studies used "radiothermy" and "diathermy" to induce heat injury and were careful to avoid use of the word "heatstroke". Daily and Harrison in 1948 (26) described cardiac output, $O_2$ consumption, A-$VO_2$ differences, mean arterial and atrial pressures in fatal dog "pyrexia", and compared various modes of external cooling therapy on the survival rates of rats heated until they convulsed.

The further development of animal models for the study of heatstroke was prevented by the a priori assumption that pathogenesis of human heatstroke depended on failure of the sweating mechanisms. This has been refuted (17,27) and heatstroke has been redefined by Kew (17) as "a state of acute thermoregulatory failure which follows exposure to high environmental temperatures and which

manifests with disturbances of the central nervous system and hyperpyrexia". This led, in 1973, to the definition of a heatstroke model in rats by Hubbard et al. (20) and in dogs by shapiro (18) and by Bynum et al. (19). Shapiro (10) and Bynum et al. (27) have described the biochemical and clinical similarities between dog and human heatstroke. Shapiro's study has also demonstrated that the acute event of heatstroke is a function of increased body heat load alone; physical exercise serving only a modifying function.

Progress:

Though our knowledge of heatstroke has grown vastly over the past 100 years, particularly with regard to predisposing environmental factors, the basic therapy mode remains unchanged and the basic cause of the illness is still debated. The array of biochemical, cytologic, and physiologic dysfunctions associated with heatstroke may involve virtually any or all major organ systems. Whether particular sets or constellations of these disruptions are causally related to the prime event of heatstroke or whether they are individually and inconsistently related to the evolving pathology of heatstroke is unclear.

The development of a data base which would resolve this issue and permit the exploration of therapeutic techniques, other than rapid external cooling and general medical support, has been impeded by the lack of an accepted animal model. Though a number of heat related animal studies have been performed, they have focused primarily on temperature regulation, burn injury, cancer hyperthermic therapy, and fever; the further development of animal models for the study of heatstroke has been prevented basically by the prior asusmption that the pathogenesis of human heatstroke depended on the failure of the sweating mechanisms. This assumption was recently refuted. With this change in perception, dog and rat heatstroke models have begun to evolve. We have contributed to this evolution by expanding the quantitative data base describing animal heatstroke. In particular, survival data following heatstroke (Fig. 1) and cardiovascular responses during heatstroke have been described (Fig. 2). Additionally, we have evaluated peritoneal dialysis as an alternate technique for rapid reduction of core temperature since rapid external cooling has been shown to result

in transient increases of rectal temperatures suggesting a reduction of heat transfer to the surface. Studies utilizing peritoneal dialysis for the alteration of body temperature are infrequent. Wegner in 1877 is credited with the first peritoneal dialysis experiments as he studied alterations in core temperature with cold peritoneal saline washes; while the experimental and clinical use of peritoneal dialysis has been developed for achieving or treating hypothermia, there is no reference to its use in the correction of hyperthermic states.

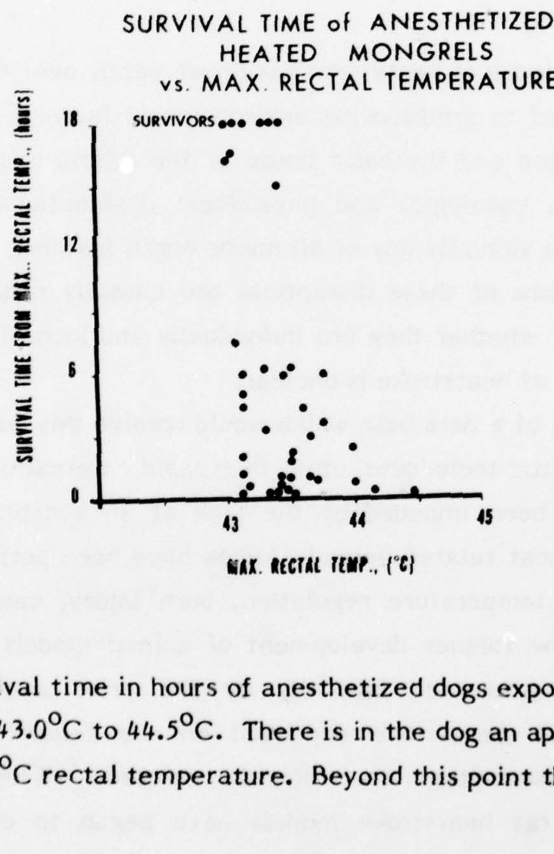


FIGURE 1. Survival time in hours of anesthetized dogs exposed to maximum rectal temperatures of 43.0°C to 44.5°C. There is in the dog an apparent critical thermal maximum at 43.5°C rectal temperature. Beyond this point there are no survivors.

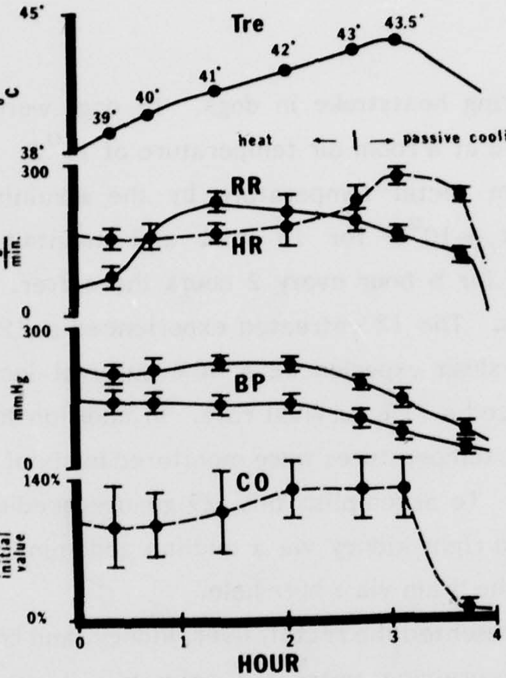


FIGURE 2. Rectal temperature (Tre), respiratory rate (RR), heart rate (HR, blood pressure (BP), and cardiac output (CO) are presented for 3 dogs heated to 43.5°C Tre. Of particular interest is the acute, rapid drop in cardiac output occurring at Tre 43.5°C. It is this drop in cardiac output which probably marks the collapse and onset of the shock like state of heatstroke.

To establish an anesthetized dog heatstroke model and to evaluate the efficiency of peritoneal dialysis for rapid reduction of core temperature and subsequent support following heatstroke, 27 healthy mongrel dogs, weighing 35 to 50 pounds were utilized. All dogs were anesthetized with nembutal and remained under anesthesia until death or until 18 hours had elapsed from the point of maximum rectal temperature. At that time, the animals were sacrificed with I.V. KCL and counted as short-term survivors.

Three of the mongrels were unheated controls and all survived the 18 hour limit. The remaining 24 were heated with water blankets to rectal temperatures of 43.0 to 43.4°C which has been established by Shapiro et al. as the critical

temperature for inducing heatstroke in dogs. 12 dogs were then uncovered and allowed to cool unaided at a room air temperature of 25°C. Seven were cooled at the time of maximum rectal temperature by the administration of a 6 liter peritoneal dialysis at 6-10°C for 15 min. and maintained with a 1.5 liter normothermic dialysis for ½ hour every 2 hours thereafter. Five were cooled by immersion in ice slush. The 12 untreated experienced a 25% survival rate. The five cooled with ice slush experienced a 40% survival incidence. Seven were dialyzed and experienced a 71% survival rate. In addition to rectal temperature, brain, liver, and kidney temperatures were monitored in six of the dialyzed and nine of the untreated dogs. To accomplish this, 25 guauge needle thermocouples were placed in the liver and right kidney via a midline abdominal incision and into the right motor cortex of the brain via a burr hole.

In Figure 3 are presented the rectal, liver, kidney, and brain core temperature responses of five nonsurviving untreated animals. Liver, kidney, and rectal temperatures cluster together prior to heating but at maximum temperatures, diverge during the passive cooling phase and reconverge at 4 hours post maximum temperature. Brain temperature remains, in general, 1 to 1.5°C cooler than the rectal during the passive cooling phase. At four hours prior to death, the rectal, liver and brain temperatures begin to diverge again and rise. The rectal, liver and kidney core temperatures never fully return to preheat values, plateauing approximately 1.5° higher at four hours post maximum temperature.

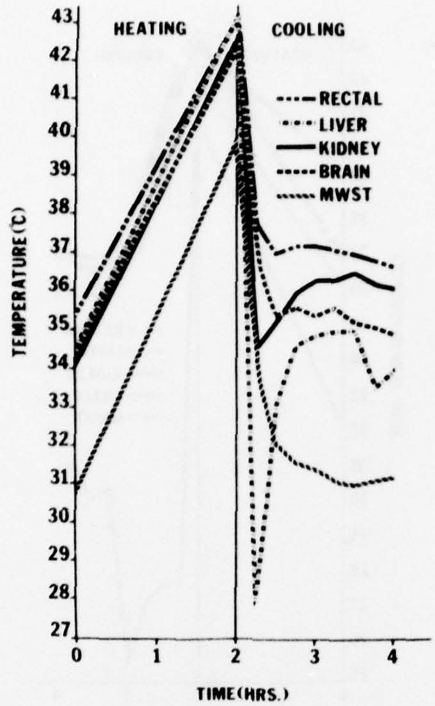


FIGURE 3. Rectal, liver, kidney, brain and mean weighted skin temperatures are presented for seven dogs heated over approximately 2 hours in a circulating water blanket. All animals were passively cooled in room air (28°C, 20% RH).

In Figure 4 are presented rectal, kidney, liver and brain core temperatures for five of the dialyzed survivor group. The core temperatures are dramatically reduced to within the normal range within 15 minutes with 6-10°C peritoneal dialysis. The temperatures display a marked spread of 2.5°C over much of the 18 hour monitoring period.

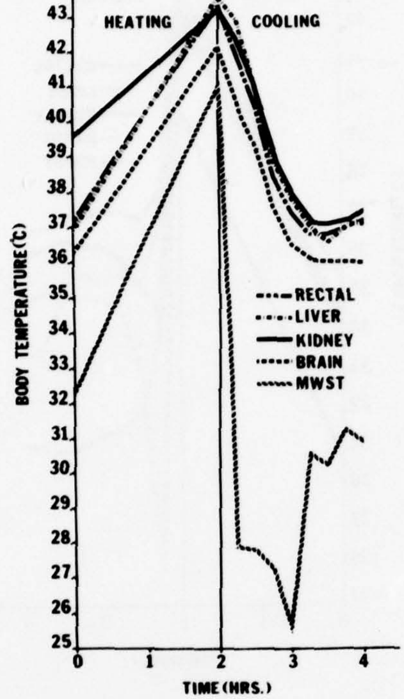


FIGURE 4. Rectal, liver, kidney, brain and mean weighted skin temperatures are presented for five dogs heated over approximately 2 hours in a circulating water blanket. All animals were cooled by being surrounded in the plastic bags filled with ice slush.

In Figure 5 are presented rectal, kidney, liver and brain core temperatures for five of the surface cooled dogs. Peritoneal dialysis is approximately six times as rapid as slush cooling and nine times as rapid as cooling in room air.

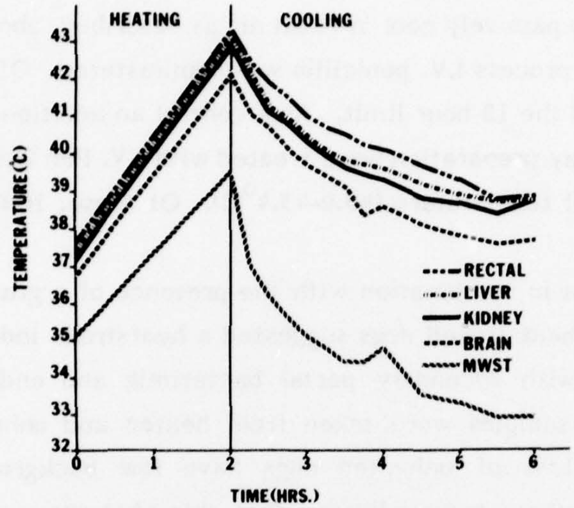


FIGURE 5. Rectal, liver, kidney, brain and mean weighted skin temperatures are presented for five dogs heated over approximately 2 hours in a circulating water blanket. All animals were cooled by peritoneal dialysis (6-10$^{o}$C).

In studies utilizing the mongrel heatstroke model, pathologic findings by histologic and electron microscopic examination of all cadaver major organ systems demonstrated lesions only in the liver, which were limited to congestion, focal perivascular inflammation and glycogen stores depletion. The particular pattern of hepatic pathology suggested an invasive process, which stimulated us to culture the major organ systems in heatstroked dogs which had not experienced invasive monitoring techniques. These cultures revealed a predominance of pathologic E. coli overgrowths in the liver as opposed to the more accepted normal canine hepatic flora of clostridia. To determine if these bacteria or their toxic by-products contribute to the pathology of heatstroke, a group of 16 dogs were treated for four consecutive days with neomycin, tetracycline, $MgSO_4$ purges and Fleets enemas in an effort to reduce body flora, and then heated under anesthesia to a

rectal temperature of 43.0-43.4°C without invasive monitoring techniques. They were allowed to passively cool in room air as described above. During the heating and monitoring process I.V. penicillin was administered. Of the dogs treated, 75% survived beyond the 18 hour limit. As a control an additional 6 "heatstroked" dogs without the 4 day preparation were treated with I.V. Pen G initiated at the point of maximum rectal temperature (43.0-43.4°C). Of these, 16.6% survived beyond the 18 hour limit.

These data in combination with the presence of a gram negative overgrowth of the liver in heatstroked dogs suggested a heatstroke induced breakdown of gut wall defenses with secondary portal bacterimia and endotoxemia. Therefore, jugular plasma samples were taken from heated and unheated dogs. The data indicate that 15% of unheated dogs have low background levels of plasma endotoxin. Further study indicated that this phenomena is limited to dogs and humans and does not occur in mice, rats, rabbits, pigs or monkeys.

The data also indicated that rising levels of plasma endotoxin were present in 50% of those animals surviving more than one hour beyond the time of maximum rectal temperature. These data in combination with the antibiotic data just described suggest that endotoxin plays a role in the mortality associated with heatstroke injury.

In these series of studies on anesthetized dog heatstroke model the following has been accomplished: (a.) Pathophysiologic events leading up to and immediately following heatstroke have been characterized; (b.) A new key to the etiology of heatstroke and the survival of heatstroke victims has been defined; and (c.) A therapeutic technique, peritoneal dialysis, for heatstroke victims has been defined which is consistent with the treatment of endotoxemia and which in the experimental animal cools more rapidly than conventional techniques increasing survival rates from 25% to 71%.

<u>Presentations:</u>

None

Publications:

1. Bynum, G., Patton, J. An anesthetized dog heatstroke model. The Physiologist 18:157, 1975.

2. Bynum G., Patton, J., Bowers, W., Leav, I., Wolfe, D., Hamlet, M., and Marsili, M. An anesthetized dog heatstroke model. J. Appl. Physiol.:Respirat. Environ. Exercise Physiol. 43:292-296, 1977.

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| Program Element: | 6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE |
| Project: | 3E762777AB45 Environmental Stress, Physical Fitness and Medical Factors in Military Performance |
| Work Unit: | 042 Models of Heat Disabilities: Treatment and Diagnosis |
| Study Title: | The Diagnostic and Prognostic Significance of Serum Enzymes and Electrolytes in a Rat Heatstroke Model |
| Investigators: | Roger W. Hubbard, Ph.D., Milton Mager, Ph.D., and Wilbert D. Bowers, Ph.D. |

Background:

Heat disorders have been classified into three separate categories: (a) Heat cramps, (b) Heat exhaustion and (c) Heatstroke (1). )f these three, the most serious is acute heatstroke which results in widespread tissue injury and death (2). In contrast to the form that characteristically affects the ill or the aged, exertion induced heatstroke can affect healthy young individuals engaged in strenuous physical activity (3). This form of heatstroke has been observed in humans working on relatively cool days (4) and has affected conditioned athletes (3,5,6) as well as untrained, unacclimatized and overweight individuals (2,7,8,9). As recently discussed by Shibolet et al. (10), the distinction between heat exhaustion and heatstroke is probably artificial, the yardsticks for this differentiation depending on the time of measurements and observations. In the setting of physical exertion in hot weather, collapse with fever of a previously healthy individual should a priori be diagnosed as heatstroke, unless another cause is obvious. Furthermore, reliance on the three "classical" yardsticks for heatstroke diagnosis: coma, hot dry skin, and fever over 41.3°C (11), can readily lead to underdiagnosis. Thus, too rigorous adherance to criteria such as minimum body temperature or absence

This conclusion is completely supported by our recent observations in rats (12,13) that the incidence of heatstroke mortality begins at exhaustion at a core temperature of 40.4°C and the mortality increases as a function of either rising core temperature or an integrated measurement of the time and intensity of hyperthermia. The purpose of this current research was to use the rat model

system to develop clinical criteria for heat injury diagnosis and prognosis.

Progress:

A total of 171 untrained, unacclimatized and unanesthetized laboratory rats weighing between 485 and 545 g were fasted and either run to exhaustion at $5^{o}C$ (n=13), at 20, 26 or $30^{o}C$ (n=57) or were restrained and heated at an ambient temperature of $41.5^{o}C$ (n=81) or served as controls (n=20). Post-fast body weights for all animals were equivalent to 486 $\pm$ 12 g. Core temperatures (Tre) were measured with a 6.5 cm rectal probe.

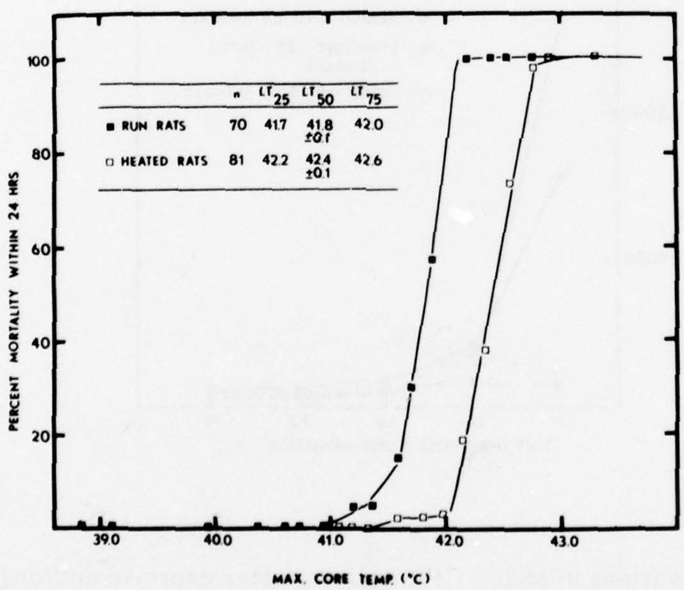


FIGURE 1. Dose-response curves of percent mortality versus the maximum core temperature of both run-exhausted and restrained-heated rats.

These curves demonstrate a continuum of increasing incidence of death with increasing severity of hyperthermia, i.e., the existence within this population of both heat-sensitive and heat-resistant animals; and confirm the observation (13)

that hyperthermia induced by working to exhaustion can be lethal to some individuals, while enduring an equivalent heat load at rest is not.

Venous blood (1.5 ml, tail vein) was drawn at 30 min, 24, 48, 72 and 96 hr post experimentation or agonally (terminal convulsions or apnea). Pre-agonal samples were replaced with an equal volume of saline. In Fig. 2, is shown the time course, post-experimentation, of the serum enzyme creatine phosphokinase (CPK) whose origin is chiefly skeletal and cardiac muscle.

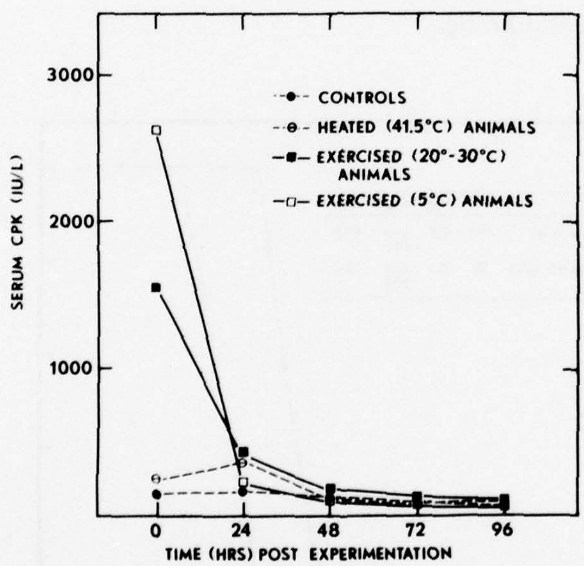


FIGURE 2. Elevations in serum CPK activity after exercise and/or hyperthermia.

This enzyme increases in serum following a variety of stressful situations including strenuous exercise (14) and heatstroke (15). Peak values in CPK were obtained immediately post-exhaustion (30 min) and then declined rapidly thereafter. As shown in Table 2, rats run at 5$^{o}$C did significantly more work prior to exhaustion and had significantly greater elevations in CPK activity than rats run at or near room temperature. Heated sedentary rats did not show elevations in CPK activity to heatstroke levels (>1000 IU/L) despite profound hyperthermia (Table 2).

Thus, elevations in CPK activity appear to reflect cellular injury due to muscle work rather than hyperthermia, per se.

In Fig. 3, is shown the time-course, post-experimentation of the serum enzyme glutamic pyruvic transaminase (SGPT). This is a mitochondrial enzyme whose serum activity increases after heatstroke (15) and especially in diseases of the liver (16). Peak values in SGPT activity were obtained 24 hours post-exhaustion or heating but did not return to control levels until 72 to 96 hours. SGPT was not elevated to heatstroke levels in rats run to exhaustion at 5°C and the highest levels of SGPT activity were obtained in the sedentary heated condition (see Tables 1 and 2). Thus, the elevations in SGPT activity appeared a consequence of hyperthermia and not exhaustive work alone.

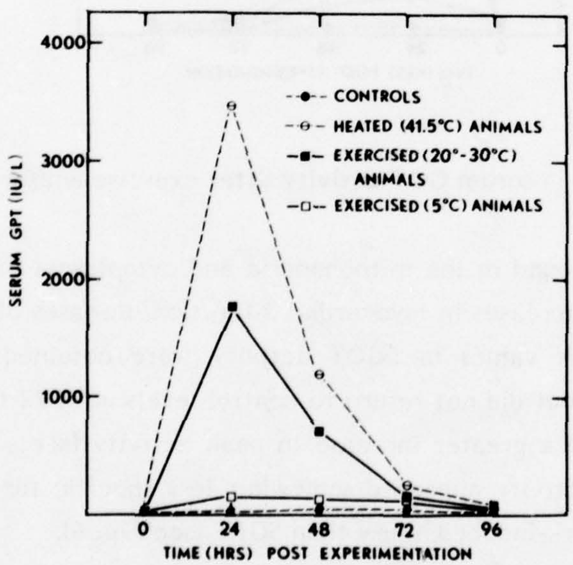


FIGURE 3. Elevations in serum GPT activity after exercise and/or hyperthermia.

In Fig. 4, is shown the time-course, post-experimentation of the serum enzyme glutamic oxalacetictransaminase (SGOT).

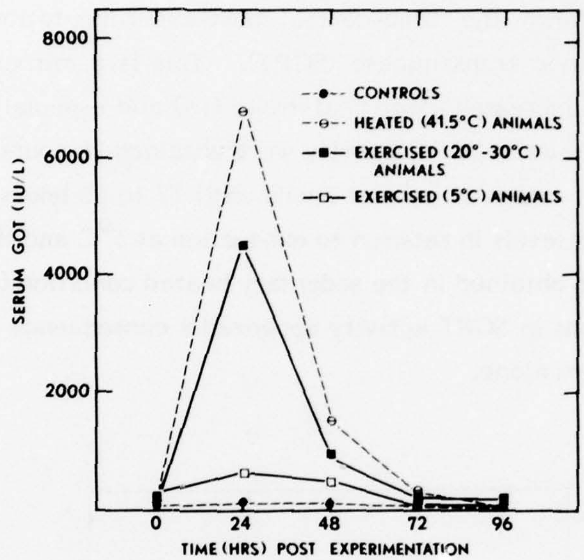


FIGURE 4. Elevations in serum GOT activity after exercise and/or hyperthermia.

This enzyme is found in the mitochondria and cytoplasma of most cells, and its activity in serum increases in myocardial infarction, diseases of muscle (16) and heatstroke (15). Peak values in SGOT activity were obtained 24 hours post-exhaustion or heating but did not return to control levels until 72 to 96 hours later. This enzyme displayed a greater increase in peak activity (see scale) than either CPK or SGPT. Its activity appeared somewhat less specific for heat injury and more influenced by work-induced injury than SGPT (see Fig. 6).

Table 1 demonstrates the relationship between the severity of hyperthermia in degree-minutes and to maximum rectal temperature (Tre max) versus serum transaminase activity.

TABLE 1 - ELEVATIONS IN SERUM ENZYME ACTIVITY OF RESTRAINED-HEATED RATS

| GROUP[a] | N | Tre MAX (°C) | HYPERTHERMIC AREA[b] (DEG-MIN) | ENZYME ACTIVITY POST-STRESS (IU/L) 30' CPK | 24 H SGPT | 24 H SGOT |
|---|---|---|---|---|---|---|
| # 1 SGPT LEVELS 0-50 IU/L | 18 | 41.7 ± 0.3 | 27.3 ± 9.1 | 141 ± 105 | 31 ± 5 | 134 ± 42 |
| # 2 SGPT LEVELS 50-500 IU/L | 15 | 41.9* ± 0.3 | 33.9* ± 10.4 | 161 ± 102 | 170* ± 142 | 409* ± 328 |
| # 3 SGPT LEVELS >500 IU/L | 24 | 42.3* ± 0.2 | 47.1* ± 9.8 | 355 ± 628 | 3635* ± 2942 (23)[c] | 6881* ± 5882 (21) |

[a]THE SURVIVING RATS WERE ASSIGNED TO ONE OF THREE DATA GROUPS BASED ON THE VALUE OF THE 24 H SGPT.

[b]AREA $\propto \sum$ TIME INTERVAL ( 2 to 6 MIN ) X 1/2 [°C ABOVE 40.4°C AT START OF INTERVAL + °C ABOVE 40.4°C AT END OF INTERVAL].

[c]NUMBERS IN PARENTHESES = N RATS.

*P<0.05 BETWEEN MEAN AND MEAN ABOVE IT.

A total of 57 restrained-heated survivors were divided into three groups based on the range of 24 hr SGPT activity: Group 1, 0-50 IU/L; Group 2, 50-500 IU/L; Group 3, 500 IU/L. Fractional increases in either hyperthermia (degree-minutes) or Tre max were associated with exponential increases in enzyme activities of both SGPT and SGOT, but not CPK. To our knowledge, this is the first experimental demonstration of this qualitative and quantitative relationship between hyperthermia and these resultant indices of tissue injury.

In Figs. 5 and 6 are shown dose response curves of both run and heated rats which compare maximum core temperatures versus the percentages of rats with elevations in serum GPT and GOT to heatstroke levels (> 1000 IU/L, 24 hr).

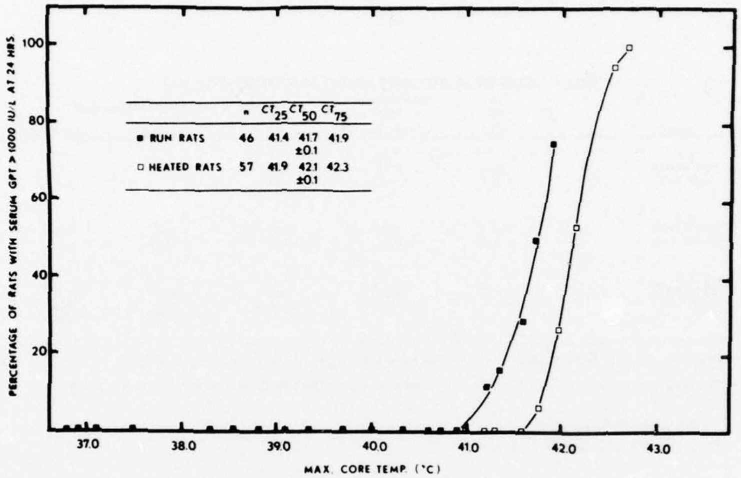


FIGURE 5. Dose-response curves of both run-exhausted and restrained-heated rats comparing maximum core temperatures versus the percentage of rats with elevations in serum GPT to heatstroke levels.

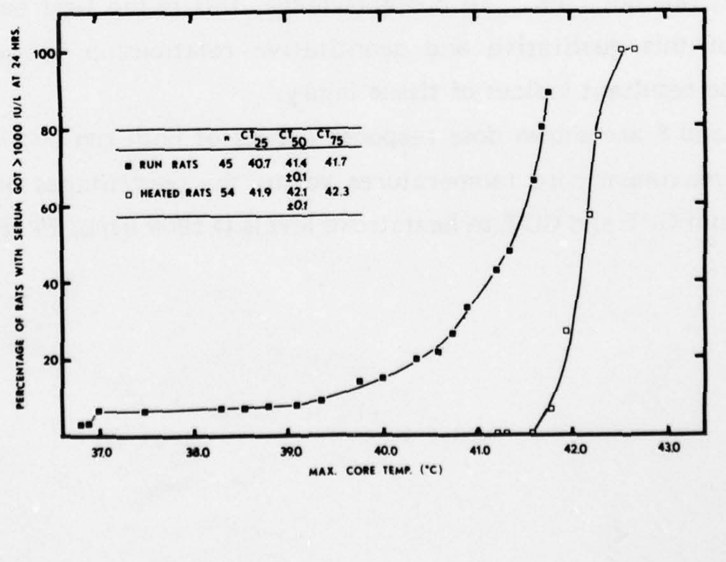


FIGURE 6. Dose-response curves of both run-exhausted and restrained-heated rats comparing maximum core temperatures versus the percentage of rats with elevations in serum GOT to heatstroke levels.

The maximum core temperature at which 50% of the restrained-heated rats showed heatstroke elevations in SGPT and SGOT were both 42.1 $\pm$ 0.1°C. This is slightly less than the maximum core temperature (42.4 $\pm$ 0.1°C, Fig. 1) producing death in 50% of the animals within 24 hr. Likewise, the LT50 for run-exhausted rats (Fig. 1) was a maximum core temperature of 41.8 $\pm$ 0.1°C and the 50% incidence of heatstroke elevations in SGPT and SGOT occurred at correspondingly lower temperatures of 41.7 $\pm$ 0.1°C and 41.4 $\pm$ 0.1°C, respectively. Finally, although the incidence of elevation in both SGPT and SGOT (Fig. 5 and 6) in restrained-heated rats is identical, this is not the case for run-exhausted animals. Whereas the incidence of elevated SGPT in run rats (Fig. 5) occurred at core temperatures above 41°C, the LT 25 for SGOT elevations was a core temperature of 40.7°C. Since heatstroke level elevations in SGOT occurred in a small percentage of exhausted-normothermic rats, this can be attributed primarily to exercise-induced injury. Further increases in the incidence of elevated SGOT (above 40.5°C, Fig. 6), appears due to the combined effects of heat plus work. These curves demonstrate: a) a continuum of increasing incidence of cellular injury with increasing severity of hyperthermia, b) the existence within this population of both heat sensitive and heat resistant individuals, and c) an experimental demonstration that hyperthermia induced by working to exhaustion can produce serious tissue injury in some individuals while enduring an equivalent heat load at rest does not.

The use of these three enzymes as an aid to diagnosis is demonstrated in Table 2. This data represents the qualitative changes associated with either work without hyperthermia (Group 1), work with hyperthermia (Group 2) or hyperthermia alone (Group 3). No attempt was made in this table to separate the results according to whether the rats survived or died. Three distinct patterns of peak enzyme activity emerged; Group 1 with the highest work output and lowest Tre max had the highest 30 min CPK activity, the lowest 24 hr SGPT and a moderate SGOT elevation. Group 2 with a lower work output and higher Tre max had high CPK activity but lower than Group 1, and higher SGPT and SGOT activity. Sedentary Group 3 had the highest Tre max and the lowest CPK levels of all groups, while SGPT and SGOT activities were significantly higher than Group 1 but not Group 2.

TABLE 2 - ELEVATIONS IN SERUM ENZYME ACTIVITY AFTER EXERCISE AND/OR BODY HEATING

| GROUP AND CONDITIONS | N | PERCENT FATALITIES IN 24 H | Tre MAX (°C) | WORK DONE (Kg-m) | ENZYME ACTIVITY POST-STRESS (IU/L) 30' CPK | 24 H SGPT | 24 H SGOT |
|---|---|---|---|---|---|---|---|
| # 1 RUN TO EXH AT 5°C | 13 | 0% | 38.2 ± 1.1 | 81 ± 33 | 2818 ± 1718 | 125 ± 81 | 637 ± 376 |
| # 2 RUN TO EXH AT 20,26, or 30°C | 57 | 42% (24)+ | 41.5* ± 1.0 | 38* ± 18 | 1776* ± 1931 (55) | 1029* ± 1570 (36) | 2457* ± 3694 (32) |
| # 3 HEATED AT 41.5°C | 81 | 31% (25) | 42.2* ± 0.4 | - | 245* ± 195 (80) | 1828 ± 3396 (67) | 3678 ± 5832 (64) |
| # 4† CONTROL | 20 | 0% | 37.1 ± 0.5 | - | 143 ± 58 (19) | 26 ± 6 | 84 ± 19 (14) |

†ALL CONTROL VALUES SIGNIFICANTLY DIFFERENT ($P<0.05$) FROM EXPERIMENTALS.

+NUMBERS IN PARENTHESES = N RATS.

*$P<0.05$ BETWEEN MEAN AND MEAN ABOVE IT.

The results shown in Table 3 depict the clinical factors differentiating between controls, survivors and fatalities approximately 30 minutes after heating or running to exhaustion while all animals were still alive.

TABLE 3 - CLINICAL FACTORS DIFFERENTIATING BETWEEN HEATSTROKE SURVIVORS AND FATALITIES 30 MINUTES POST-STRESS

| GROUP | N | SAMPLE TIME | Tre MAX | HYPERTHERMIC AREA | COOLING RATE (°C/MIN) | TOTAL PROTEIN (g%) | $Na^+$ (mEq/L) | $K^+$ (mEq/L) | CPK (IU/L) | SGPT (IU/L) | SGOT (IU/L) | HCT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CONTROLS | 20 | POST FAST | 37.1 ± 0.5 (12) | — | — | 7.0 ± 0.4 | 141 ± 8 | 5.4 ± 0.5 | 143 ± 58 (19) | 25 ± 7 | 70 ± 11 (16) | 49 ± 2 |
| HEATED SURVIVORS | 56 | 30 MIN | 42.0† ± 0.4 | 37.4 ± 13 | 0.094 ± 0.033 | 7.0 ± 0.4 | 146† ± 8 | 4.8† ± 0.6 | 230† ± 211 | 32† ± 10 | 108† ± 24 (54) | 50† ± 2 |
| HEATED FATALITIES | 25 | 30 MIN | 42.5†* ± 0.4 | 58.1* ± 16.6 | 0.066* ± 0.023 (24) | 7.0 ± 0.4 | 150† ± 15 | 6.1* ± 1.9 | 281† ± 149 | 34† ± 14 | 133†* ± 47 | 52†* ± 4 |
| RUN SURVIVORS | 46 | 30 MIN | 40.9† ± 0.9 (37) | 30.8 ± 17.3 (16) | 0.041 ± 0.025 (33) | 6.8 ± 0.5 (43) | 143 ± 8 | 5.1† ± 0.6 | 1710† ± 1420 | 41† ± 20 | 170† ± 69 (42) | 48† ± 2 (43) |
| RUN FATALITIES | 24 | 30 MIN | 42.3†* ± 0.4 | 76.0* ± 33.9 (13) | 0.027* ± 0.031 | 7.4†* ± 0.8 (20) | 146 ± 18 (22) | 7.0†* ± 1.9 (22) | 2531†* ± 2649 (22) | 58†* ± 47 (21) | 278†* ± 161 (20) | 53†* ± 5 (20) |

*SIGNIFICANTLY DIFFERENT FROM SURVIVORS.

†SIGNIFICANTLY DIFFERENT FROM CONTROL.

All animals found alive 24 hr after testing were counted as survivors. In contrast to survivors, potential fatalities had, in general, greater heating areas (degree-minutes), higher core temperatures, slower cooling rates and elevated hematocrits. Run-exhausted fatalities displayed significantly greater elevations in total protein and serum enzymes than run-exhausted survivors. The most consistent difference found between potential survivors and fatalities was the early divergence in serum potassium. Fatalities had significantly higher serum levels than survivors due, in part, to the significant decrease of potassium below control values in the survivors.

TABLE 4 - RAPID CHANGE IN SERUM ELECTROLYTES AND ENZYME ACTIVITY WITH FATAL HEATSTROKE IN RATS

| GROUP | N | SAMPLE TIME | $T_{re}$ MAX | HYPERTHERMIC AREA | HCT | TOTAL PROTEIN (g%) | $Na^+$ (mEq/L) | $K^+$ (mEq/L) | CPK (IU/L) | SGPT (IU/L) | SGOT (IU/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| # 1 - HEATED + RUN FATALITIES AGONAL 3-24 H | 13 | 30 MIN | 42.4 ± 0.2 | 59.0 ± 13.3 | 50 ± 2 | 6.8 ± 0.4 | 144 ± 6 | 5.2 ± 1.3 | 304 ± 164 | 29 ± 16 | 144 ± 49 |
| # 1A - HEATED + RUN FATALITIES AGONAL 3-24 H | 13 | TERMINAL | | | 49 ± 8 | 6.7 ± 1.0 | 148 ± 10 (11) | 8.0* ± 2.6 (11) | 1478* ± 1345 | 2131* ± 2484 (12) | 8288* ± 8532 |
| # 2 - HEATED FATALITIES AGONAL <2 H | 9 | 30 MIN | 42.7† ± 0.5 | 58.5 ± 17.2 | 56† ± 5 | 7.1 ± 0.4 | 162† ± 18 (8) | 7.9† ± 1.9 | 370 ± 187 (8) | 38 ± 14 (8) | 138 ± 36 (8) |
| # 3 - RUN FATALITIES AGONAL <2 H | 13 | 30 MIN | 42.4 ± 0.5 | 90.5† ± 38.9 (7) | 56† ± 4 | 7.8† ± 0.8 | 145 ± 22 | 8.4† ± 1.2 | 2857† ± 2239 (11) | 68† ± 52 (11) | 322† ± 146 (11) |

*$P<0.05$ (1A VS 1)

†$P<0.05$ (2 + 3 VS 1)

GROUP 1A REPRESENT AGONAL SAMPLES DRAWN DURING TERMINAL CONVULSIONS (3-24 H) FROM GROUP 1 RATS.

GROUP 2 + 3 REPRESENT HEATED AND RUN FATALITIES OCCURRING IN LESS THAN 2 H POST-STRESS.

The rapid changes in serum electrolytes and enzyme activity in fatal heatstroke is shown in Table 4. Group 1 combines both run and heated fatalities whose blood was drawn at 30 min post-stress and for which there were agonal samples drawn from these same animals during terminal convulsions between 3 and 24 hr later (Group 1A). For comparison, Groups 2 and 3 represent heated and run fatalities which died in less than 2 hr post-stress. As expected there were highly

significant increases in serum potassium and enzyme activity levels during the interval between the 30 min and agonal samples (Group 1 vs 1A). Since these fatalities occurred between 3-24 hr post-stress, these factors are grave prognostic indicators. In addition, (Groups 2 and 3 vs 1), the fatalities occurring in less than 2 hr post-stress likewise had significantly higher hematocrits and serum potassium levels but with the exception of serum CPK from Group 3, the rise in serum enzyme activity to heatstroke levels was precluded by death.

In summary, the human literature has suggested that both exercise and heat could elevate certain key serum enzymes and that the level of their activity within the first 24 hours following heatstroke had a good correlation with subsequent mortality. The results from this rat model demonstrate under controlled conditions that both mortality and enzyme release are a function of the time and/or the intensity of body heating. This data further confirms the validity of this model. Additionally, the following new information was obtained;

a) Fractional increases in hyperthermia are associated with exponential increases in SGPT, SGOT but not CPK. Future research should identify both the source and cause of enzyme release (i.e. heat, ischemia, pH or some combination of these).

b) The pattern in enzyme activity of SGPT, SGOT and CPK can distinguish between work without hyperthermia, work with hyperthermia and hyperthermia alone. Besides the obvious aid to diagnosis, these results should be useful in evaluating the role of mixed stressors in future studies.

c) Dose-response curves suggest that working to exhaustion lowers the threshold for both heatstroke mortality and cellular injury. These curves should provide a new research tool for unravelling the complex contributions of heat and work to cell injury and death.

d) Rapid change in key enzymes and electrolytes are grave prognostic indicators. Future research must determine whether the decrease of serum potassium in survivors and increase in fatalities is related to coincident changes in acid-base balance, i.e. a change from respiratory alkalosis to metabolic acidosis.

Presentations:

1. Hubbard, R. W., R. E. L. Criss, L. P. Elliott, and I. V. Sils. Use of serum enzymes to differentiate in the rat between heat and/or work induced disorders. Presented, APS Annual Fall Meeting, Hollywood, Florida, October 9-14, 1977.

2. Mager, M., R. W. Hubbard, W. T. Matthew, C. Kelly, G. Sheldon, and J. W. Ratteree. Biophysical and clinical chemical indices of potential fatalities in a rat heatstroke model. Presented, APS Annual Fall Meeting, Hollywood, Florida, October 9-14, 1977.

Publications:

1. Hubbard, R. W., W. T. Matthew, J. D. Linduska, F. C. Curtis, W. D. Bowers, I. Leav, and M. Mager. The laboratory rat as a model for hyperthermic syndromes in humans. Am. J. Physiol. 231(4):1119-1123, 1976.

2. Hubbard, R. W., W. D. Bowers, W. T. Matthew, F. C. Curtis, R. E. L. Criss, G. M. Sheldon, and J. W. Ratteree. Rat model of acute heatstroke mortality. J. Appl. Phyisol.: Respirat. Environ. Exercise Physiol. 42(6):809-816, 1977.

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| RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY | | 1. AGENCY ACCESSION* | 2. DATE OF SUMMARY* | REPORT CONTROL SYMBOL |
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| 3. DATE PREV SUM'RY | 4. KIND OF SUMMARY | 5. SUMMARY SCTY* | 6. WORK SECURITY* | 7. REGRADING* | 8a. DISB'N INSTR'N | 8b. SPECIFIC DATA-CONTRACTOR ACCESS | 9. LEVEL OF SUM |
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| 10. NO./CODES:* | PROGRAM ELEMENT | PROJECT NUMBER | TASK AREA NUMBER | WORK UNIT NUMBER |
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| a. PRIMARY | 6.27.77.A | 3E762777A845 | 00 | 043 |
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11. TITLE (Precede with Security Classification Code)*

(U)Physical Fitness Level Requirements and Evaluation for the US Army(22)

12. SCIENTIFIC AND TECHNOLOGICAL AREAS*

012900 Physiology; 012500 Personnel Training & Evaluation

| 13. START DATE | 14. ESTIMATED COMPLETION DATE | 15. FUNDING AGENCY | 16. PERFORMANCE METHOD |
|---|---|---|---|
| 76 10 | CONT | DA | C. In-House |

17. CONTRACT/GRANT

a. DATES/EFFECTIVE: EXPIRATION:
b. NUMBER:* NOT APPLICABLE
c. TYPE: d. AMOUNT:
e. KIND OF AWARD: f. CUM. AMT.

| 18. RESOURCES ESTIMATE | | a. PROFESSIONAL MAN YRS | b. FUNDS (In thousands) |
|---|---|---|---|
| FISCAL YEAR | PRECEDING 77 | 5. | 243 |
| | CURRENT 78 | 15.3 | 183.2 |

19. RESPONSIBLE DOD ORGANIZATION

NAME:* USA RSCH INST OF ENV MED

ADDRESS:* NATICK, MASSACHUSETTS 01760

RESPONSIBLE INDIVIDUAL

NAME: DANGERFIELD, HARRY G., M.D., COL, MC

TELEPHONE: 955-2811

20. PERFORMING ORGANIZATION

NAME:* USA RSCH INST OF ENV MED

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PRINCIPAL INVESTIGATOR (Furnish SSAN if U.S. Academic Institution)

NAME:* VOGEL, James A. Ph.D.

TELEPHONE: 955-2800

SOCIAL SECURITY ACCOUNT NUMBER:

ASSOCIATE INVESTIGATORS

NAME: KOWAL, Dennis M. CPT, MSC

NAME:

DA

21. GENERAL USE

Foreign Intelligence Not Considered

22. KEYWORDS (Precede EACH with Security Classification Code) (U)Job Fitness Requirements; (U)Physical Fitness Standards; (U) Energy Cost; (U) Military Occupational Specialties; (U) Muscle Strength

23. TECHNICAL OBJECTIVE,* 24. APPROACH, 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)

23. (U) A sound physical fitness training program in the Army should include a scientific matching of fitness standards to specific job requirements. New enlistees should also be screened for physical fitness and classified acocrding to physical capacity for job eligibility.

24. (U) Specific studies will include: (1) Determination of fitness requirements (aerobic, anaerobic strength) for each job grouping; (2) Develop a physical fitness battery suitable for screneing new accessions at Armed Forces Entrance Examination Stations and MOS qualification; and (3) Survey levels of fitness where appropriate to insure adequacy and appropriateness of training programs.

25. (U)76 10 - 77 09 (1) The first phase of a combined effort with TRADOC to determine the physical fitness requirements of personnel in sedentary jobs was initiated in April 1977 at Ft. Sam Houston and Ft. Bliss, Texas. Fitness requirements were to be based on the physiological cost of performing common soldiering tasks. This project was prematurely cancelled due to lack of medical support from the Army Health Services Command. (2) A physical fitness test battery to predict physical work capacity for job eligibility for application at AFEESs has been developed and will be pilot tested Jan-June 1978. (3) The second phase of the combined effort with TRADOC to determine the fitness requirements of physically active jobs is presently being designed.

*Available to contractors upon originator's approval



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|---|---|
| Program Element: | 6.27.77.A ENVIRONMENTAL STRESS PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE |
| Project: | 3E762777A845 |
| Work Unit: | 043 Physical Fitness Level Requirements and Evaluation for the US Army |
| Study Title: | Determination of the Physical Fitness Requirements of Sedentary MOSs in the Army |
| Investigators: | James A. Vogel, Ph.D., John F. Patton, Ph.D., Dennis M. Kowal, CPT, MSC, William L. Daniels, CPT, MSC, and Dan S. Sharp, CPT, MC |

Background:

The Army Deputy Chief of Staff for Personnel (DCSPER) has instructed The Training and Doctrine Command (TRADOC) and the Office of The Surgeon General to revamp the Army's physical training program so that standards and training are realigned to meet the specific requirements of military occupation specialties (MOS), irrespective of gender and age. DCSPER's rationale for establishing fitness requirements by MOS, in contrast to individual requirements, stems from several considerations: (a) the large influx of women into physically active MOS; (b) a need for a more efficient selection and qualification system which takes into consideration the physical capacity to perform MOS tasks; and (c) a need to conserve manpower in the Army by establishing a close fit between individual capability and job requirement. In essence, with the size of the Army being trimmed at the same time that many new entrants are in a lower range of fitness, it is imperative that fitness requirements for jobs be scientifically determined so that manpower can be more efficiently utilized. A recent study by this Institute (1) demonstrated that females now entering the Army have 25% less aerobic fitness and 25-50% less muscle strength than men.

The general approach selected by TRADOC and this Institute to establish these requirements is outlined below:

Step 1: Group individual MOS by inspection into clusters of like MOS based on stamina and strength demand.

Step 2: Identify representative tasks for each MOS cluster.

Step 3: Measure physiological demand rate (energy, force) of each task.

Step 4: Identify tasks with highest energy demand and highest force demand - establish these demands as MOS cluster requirement.

Step 5: Convert requirement from physiological units into performance units and establish as MOS cluster fitness standard.

The first step in this process has been accomplished which resulted in the following MOS clusters:

| | Grouped by | | |
|---|---|---|---|
| Cluster | Strength | | Stamina |
| Designation | Upper Body | Lower Body | |
| Baseline | Low | Low | Low |
| Alpha | Medium | High | High |
| Bravo | High | Medium | Medium |
| Charlie | High | Medium | Low-Med |
| Delta | High | High | Low-Med |
| Echo | Medium | Medium | Medium |
| Foxtrot | Medium | Medium | High-Med |

Thus, the first cluster, Baseline, represents all those MOS that, by inspection, require the minimum level of fitness, i.e., those MOS that are generally "sedentary" in nature and are not dependent upon a specific level of physical fitness to meet job demands.

Since this Baseline cluster has no physical tasks of its own with which to base a fitness requirement, TRADOC has decided that the requirement be based on a group of six tasks called "common soldiering tasks". These tasks have been established as a necessary minimum for all soldiers, irrespective of MOS, to be capable of performing in a defensive war time situation. Thus, the representative tasks for the Baseline cluster have been established (Step-2) as the following six common soldiering tasks:

1. Five miles in two hours.

2. Dig a one-man emplacement in 45 minutes.
3. Lift and carry 50 lbs bag 50 meters, repeating 8 times, in 10 minutes.
4. Grenade throw to target: 15, 25 and 35 meters.
5. Low and high crawl for 75 meters in 90 seconds.
6. Rush 75 meters with 2 intermediate stops of 2 seconds each, within 25 seconds.

The representative tasks of the remaining six clusters are still being formulated.

The third step is to measure the physiological demand for each representative task, both in terms of energy cost and force/muscle strength. The current status of this project is Step-3 for the Baseline cluster, i.e., determining the physiological cost of the common soldiering tasks.

Progress:

A research study to accomplish Step-3 for the Baseline cluster has been designed and scheduled to begin on 9 January 1978. The study will employ male and female recruits at the Ft. Jackson Training Center. Energy cost will be measured during the performance of the soldiering tasks with portable respirometers (2). Force demands will be determined by the mass and distances moved. Cost measures of other MOS clusters are projected to begin by the end of FY 78.

Presentations:

None.

Publications:

None.

## LITERATURE CITED

1. Vogel, J. A., M. U. Ramos and J. F. Patton. Comparisons of aerobic power and muscle strength between men and women entering the U.S. Army. American College of Sports Medicine, May 1977.

2. Consolazio, C. F., R. E. Johnson and L. J. Pecora. Physiological Measurements of Metabolic Functions in Man (pgs 40-50), McGraw-Hill Book Co., New York, 1963.

AD-A060 886 ARMY RESEARCH INST OF ENVIRONMENTAL MEDICINE NATICK MASS F/G 6/5
ANNUAL PROGRESS REPORT, FISCAL YEAR 1977.(U)
OCT 77

UNCLASSIFIED NL

3 OF 5
AD A060886

OF

0886

(83045)

| RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY | 1. AGENCY ACCESSION* | 2. DATE OF SUMMARY* | REPORT CONTROL SYMBOL |
|---|---|---|---|
| | DA OB 6142 | 77 10 01 | DD-DR&E(AR)636 |

| 3. DATE PREV SUM'RY | 4. KIND OF SUMMARY | 5. SUMMARY SCTY* | 6. WORK SECURITY* | 7. REGRADING* | 8a. DISB'N INSTR'N | 8b. SPECIFIC DATA-CONTRACTOR ACCESS | 9. LEVEL OF SUM |
|---|---|---|---|---|---|---|---|
| 77 09 02 | D. Change | U | U | NA | NL | ☒ YES ☐ NO | A. WORK UNIT |

| 10. NO./CODES:* | PROGRAM ELEMENT | PROJECT NUMBER | TASK AREA NUMBER | WORK UNIT NUMBER |
|---|---|---|---|---|
| a. PRIMARY | 6.27.77.A | 3E762777A845 | 00 | 045 |
| b. CONTRIBUTING | | | | |
| c. XXXXXXXNG | CARDS 114f | | | |

11. TITLE (Precede with Security Classification Code)*
(U) Treatment of Cold Injury (22)

12. SCIENTIFIC AND TECHNOLOGICAL AREAS* 002300 Biochemistry; 002600 Biology; 012900 Physiology; 005400 Environmental Biology; 003500 Clinical Medicine

| 13. START DATE | 14. ESTIMATED COMPLETION DATE | 15. FUNDING AGENCY | 16. PERFORMANCE METHOD |
|---|---|---|---|
| 76 10 | CONT | DA | C. In-House |

17. CONTRACT/GRANT
a. DATES/EFFECTIVE: EXPIRATION:
b. NUMBER:* NOT APPLICABLE
c. TYPE: d. AMOUNT:
e. KIND OF AWARD: f. CUM. AMT.

| 18. RESOURCES ESTIMATE | | a. PROFESSIONAL MAN YRS | b. FUNDS (In thousands) |
|---|---|---|---|
| FISCAL YEAR | PRECEDING 77 | 3.3 | 102 |
| | CURRENT 78 | 2.3 | 53.4 |

19. RESPONSIBLE DOD ORGANIZATION
NAME:* USA RSCH INST OF ENV MED
ADDRESS:* Natick, MA 01760
RESPONSIBLE INDIVIDUAL
NAME: DANGERFIELD, HARRY G., M.D., COL, MC
TELEPHONE: 955-2811

20. PERFORMING ORGANIZATION
NAME:* USA RSCH INST OF ENV MED
ADDRESS:* Natick, MA 01760
PRINCIPAL INVESTIGATOR (Furnish SSAN if U.S. Academic Institution)
NAME:* HAMLET, Murray P., D.V.M.
TELEPHONE: 955-2865
SOCIAL SECURITY ACCOUNT NUMBER:
ASSOCIATE INVESTIGATORS
NAME:
NAME: DA

21. GENERAL USE
Foreign Intelligence Not Considered

22. KEYWORDS (Precede EACH with Security Classification Code)
(U)Cold Injury; (U)Hypothermia; (U)Fasciotomy; (U)Vasodilation; (U)Angiography

23. TECHNICAL OBJECTIVE.* 24. APPROACH, 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)

23. (U)Although cold injury is of little clinical significance in the civilian community, it has had serious impact on every Army that has attempted to fight in the cold. Hospitilization times for Korea and Second World War are 37 and 57 days respectively. Amputation and permanent loss of function and death are routine sequella. Current knowledge suggests that increased blood flow and internal methods of rewarming and surgical approaches to frostbite may decrease the hospitalization time and increase tissue salvage.

24. (U)Fasciotomy with and without vasodilators will be used on the standard frostbite animal model. Blood flow/angiography and thermographic studies will be utilized to evaluate total tissue salvage. Venous effluent from frostbitten extremities will be studied for the presence of various substances that will have an impact on tissue salvage. Internal methods of rewarming hypothermic animals will be studied for the effects on physiologic parameters that affect survival.

25. (U)76 10 - 77 09 Fasciotomy plus vasodilators gave increased short term tissue survival over non-fasciotomy and vasodilator alone. Long term 14 day tissue survival however was similar. Fasciotomy appears to increase perfusion early but other factors (emboli and vessel destruction) appear to bedetrimental late in the treatment regime. There is an increase in oxygen utilization, an increase in CPK GPT and acid phosphatase in venous serum and lymph of a frostbitten extremity. Distal fluid correlated well with lymph GPT but not CPK or acid phosphatase. Lymph flow increased 3 to 5 times and platelet counts were markedly depressed.

*Available to contractors upon originator's approval.

| | |
|---|---|
| Program Element: | 6.27.77.A ENVIRONMENTAL STRESS PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE |
| Project: | 3E762777A845 Environmental Stress Physical Fitness and Medical Factors in Military Performance |
| Work Unit: | 045 Treatment of Cold Injury |
| Study Title: | Evaluation of Biochemical Changes and Hemodynamics Following Frostbite in the Dog |
| Investigators: | Murray P. Hamlet, D.V.M., and David R. Franz, CPT, VC, D.V.M. |

## Background:

Most theories for the pathogenesis of tissue loss following frostbite can be divided into two categories: direct cellular damage from cold (1), and hypoxia and cell death resulting from destruction of the supportive vascular bed at the site of injury (2,3). In an attempt to describe aspects of the pathophysiology of frostbite in the dog, arterial venous, and lymphatic flow rates and concentrations of various humoral factors were measured in the canine rear foot before and after freezing injury.

Both moderate and severe injury groups were studied. A moderate injury involved deep foot temperature below freezing for 60 minutes and the severe injury group involved deep foot temperature below freezing for 100 minutes.

## Progress:

The study is completed with the exception of evaluation of data and electron microscopy. The following trends can be seen in the raw data: 1)Decreased utilization of $O_2$ by injured tissue is apparent following injury. 2) Enzyme intracellular origin (CPK, GPT, and Acid Phosphatase) levels are elevated in the venous serum and greatly increased in the lymph of the injured foot following injury. The enzymes selected were used as markers for membrane permiability increases

following injury: CPK (creatine phospho kinase, GPT (glutamic pyruvic transaminase), and Acid Phos. (lysosomes). CPK showed 10 to 20 fold increases in serum and as much as 60 fold increases in lymph following injury. GPT showed less increase in both serum and lymph and acid phosphatase normally increased only in lymph. Blister fluid enzyme levels correlated closely with lymph GPT but not lymph CPK or acid phosphatase. 3) Lymph flow rate commonly increased to 3-5 times control rate with the severe edema following rewarming. Lymph flow was not stopped by elevated "compartment pressures." 4) Slight decreases in plasma protein and increases in lymph protein were noted following injury, possibly indicating increased vascular permeability. 5) Total platelet counts were significantly depressed immediately following thaw and sample period. 6) Increased hemolysis of RBC's was noted in both arterial and venous blood following injury.

There are no plans to pursue the study in the immediate future. Physical preparation of the model is somewhat difficult and, as presently designed, useful only as an acute preparation. The investigator, however, believes the model shows promise not only as a means of understanding pathophysiology, but more importantly, a means of acute evalution of therapy, i.e., rewarming methods, fasciotomy, vasodilators, etc.

<u>Presentations:</u>

None.

<u>Publications:</u>

None.

## LITERATURE CITED


1. Reite, Ola Bodvar. Mechanical forces as a cause of cellular damage by freezing and thawing. Institute of Experimental Medical Research, Ullevaal Hospital, Oslo, Norway.

2. Crismon, J. M., and F. A. Furman. Studies on gangrene following cold injury: VI, capillary blood flow after cold injury, the effects of rapid rewarming and sympathetic block. J. Clin. Invest. 26, pp 468-475, 1947.

3. Weatherly-White, R. C., Bjorn Sjostrom, and Bruce C. Patton. Exp. studies in cold injury: II, pathogenesis of frostbite. JSR, Vol. 4, No. 1, 1946.

(83046)

| RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY | 1. AGENCY ACCESSION* | 2. DATE OF SUMMARY* | REPORT CONTROL SYMBOL |
|---|---|---|---|
| | DA OC 6149 | 77 10 01 | DD-DR&E(AR)636 |

| 3. DATE PREV SUM'RY | 4. KIND OF SUMMARY | 5. SUMMARY SCTY* | 6. WORK SECURITY* | 7. REGRADING* | 8a. DISB'N INSTR'N | 8b. SPECIFIC DATA-CONTRACTOR ACCESS | 9. LEVEL OF SUM |
|---|---|---|---|---|---|---|---|
| 77 06 15 | D. Change | U | U | NA | NL | ☒ YES ☐ NO | A. WORK UNIT |

| 10. NO./CODES:* | PROGRAM ELEMENT | PROJECT NUMBER | TASK AREA NUMBER | WORK UNIT NUMBER |
|---|---|---|---|---|
| a. PRIMARY | 6.27.77.A | 3E762777A845 | 00 | 046 |
| b. CONTRIBUTING | | | | |
| c. XXXXXXXX | CARDS 114f | | | |

11. TITLE (Precede with Security Classification Code)* (U) Prevention of Military Environmental Casualties by Epidemiologic Research and Information Dissemination (22)

12. SCIENTIFIC AND TECHNOLOGICAL AREAS* 012900 Physiology; 013400 Psychology; 022400 Bioengineering; 013300 Protective Equipment; 016200 Stress Physiology

| 13. START DATE | 14. ESTIMATED COMPLETION DATE | 15. FUNDING AGENCY | 16. PERFORMANCE METHOD |
|---|---|---|---|
| 74 07 | CONT | DA | C. In-House |

17. CONTRACT/GRANT

a. DATES/EFFECTIVE: EXPIRATION:

b. NUMBER:* NOT APPLICABLE

c. TYPE: d. AMOUNT:

e. KIND OF AWARD: f. CUM. AMT.

| 18. RESOURCES ESTIMATE | | a. PROFESSIONAL MAN YRS | b. FUNDS (In thousands) |
|---|---|---|---|
| FISCAL YEAR | PRECEDING 77 | 4.5 | 235 |
| | CURRENT 78 | 3.6 | 174.9 |

19. RESPONSIBLE DOD ORGANIZATION

NAME:* USA RSCH INST OF ENV MED

ADDRESS:* Natick, MA 01760

RESPONSIBLE INDIVIDUAL

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TELEPHONE: 955-2811

21. GENERAL USE

Foreign Intelligence Not Considered

20. PERFORMING ORGANIZATION

NAME:* USA RSCH INST OF ENV MED

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NAME:* JACKSON, Ronald E., MAJ, MC

TELEPHONE: 955-2813

SOCIAL SECURITY ACCOUNT NUMBER:

ASSOCIATE INVESTIGATORS HAMLET, Murray P., D.V.M.

NAME: STROSCHEIN, Leander A., Mr.

NAME: PANDOLF, Kent B., Ph.D. DA

22. KEYWORDS (Precede EACH with Security Classification Code) (U) Military Operations; (U) Performance Limits; (U) Military Tactics; (U) Environmental Medicine

23. TECHNICAL OBJECTIVE,* 24. APPROACH, 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)

23. (U) Identify environmental medicine problems in Army units as research requirements. Maintain dialogue with DA staff and line to (a) communicate research results to potential users, (b) provide assistance and resolve difficulties in interpreting and applying research, (c) identify unsolved problems. Provide a continuing source of identified, in-depth expertise on the impact of physiological and psychological status, military clothing and equipment, natural and crew compartment environments, high terrestrial elevations, and physical fitness, on the soldier's health and mission capability.

24. (U) Maintain direct liaison with DA schools, line and staff units by visits, conferences, and correspondence. Maintain reference files on climate, clothing, and equipment, and physical and physiological differences among military populations, as a base for predicting environmental impact and mission capability. Assist in preparation of training films, TB MEDs, FMs, and other doctrine; provide consultation to units planning military operations under stressful conditions; assist with doctrine for physical training and/or acclimatization.

25. (U) 76 10 - 77 09 Major cold weather exercise with field units conducted to evaluate the effects of cold stress on individual and group performance. Pre-deployment briefing on cold environments and hot environments were conducted. Presentations at civilian meetings have increased information transfer between USARIEM and civilian organizations involved in similar research efforts. Briefings and consultations with US Army Commands and units have increased liaison and provided data and information useful in the identification of new research problems. An intensive short course on "Current Concepts in Environmental (Climatic) Medicine" was presented.

*Available to contractors upon originator's approval

DD FORM 1 MAR 68 1498 PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE. DD FORMS 1498A, 1 NOV 65 AND 1498-1, 1 MAR 68 (FOR ARMY USE) ARE OBSOLETE.

| | |
|---|---|
| Program Element: | 6.27.58.A MILITARY MEDICAL INVESTIGATIONS |
| Project: | 3A62758A827 Military Environmental Medicine |
| Unit: | 046 Prevention of Military Environmental Medical Casualties by Epidemiologic Research and Information Dissemination |
| Study Title: | Behavioral Evaluation of Infantry Winter Training, 1977 |
| Investigators: | James E. McCarroll, MAJ, MSC and Joseph C. Denniston, MAJ, VC |

## Background:

Field studies of natural military groups provide important opportunities for gathering data on current problems encountered by soldiers (1) and as a source of new ideas for laboratory research. A recent study in Alaska (2) showed that simulated casualty evacuation was extremely difficult for a small unit operating alone with only its organizational equipment.

## Progress:

A field study was conducted to evaluate the effects of low environmental temperatures on an infantry battalion conducting cold weather training in the northern United States. The battalion strength at the time of the exercise was 480 Companies. The organization consisted of a Headquarters and Headquarters Company, three Rifle Companies and a Combat Support (CSC)(anti-tank, heavy mortars and scouts). One of the Rifle Companies and the CSC were observed during the exercise. Personal interviews were conducted with members of the battalion, evaluators, support personnel and visitors. All persons interviewed had previous experience in cold weather military operations.

The purposes of this study were to define the effects of environmental stress on individual and group performance, incidence and type of medical problems and social organization and how social factors affect unit performance and health in an infantry battalion undergoing winter warfare training. The following specific questions were asked:

1. How does cold affect the personal habits of soldiers and their ability to perform?

2. Is cold weather itself stressful to individuals?

3. Which "lifestyles" seem to be conducive either to performing well or poorly in the cold?

4. How knowledgeable is the individual soldier of the effects of cold upon him and of protective care measures to follow when in a cold environment?

5. What are the physiological effects of cold on individuals performing in the field?

6. What are the physical demands of winter warfare training on individuals?

7. What are the attitudes and practices of individuals with regard to the use of alcohol in the cold?

8. Did the medical support unit receive sufficient cold weather medical training to be able to function effectively?

9. How does cold affect the medical delivery system?

10. Is medical doctrine altered in order to provide medical care in a cold environment?

11. Are the force structures for medical support adequate in the cold?

12. How do casualties affect the performance of a unit and its ability to complete its mission?

13. How is tactical doctrine applied in the cold?

14. What seem to be the critical factors enabling a unit to work effectively in the cold?

15. What happens in a true emergency situation?

A Rifle Company and Combat Support Company were selected for observation.

Questionnaires were given before and after the two-week training period. The purposes of the first questionnaire were to acquire demographic data for possible later comparison with other populations, determine attitudes toward cold weather, and to obtain medical histories regarding cold weather. The second questionnaire was used to determine the range of experiences encountered by the troops during the training and the extent of their medical complaints.

Participant observers were located in different companies and platoons during the training and the bivouac phase and participated in the training along with the troops under observation. Particular attention was paid to adherence to military doctrine, participation in training, influence of formal and informal leaders, task performance, social organizations, social constraints on behavior, meals and eating patterns, feeling states and personal habits which may affect the ability to perform. Special attention was given to determine how well people cope with the harsh, cold weather, what seemed to be the variable responsible for a unit doing well or poorly and how unit and individual performance was affected by a stressful situation.

Interviews were conducted with members of the battalion, evaluators, support personnel and visitors. All had previous experience in cold weather military operations. Questions were asked on special qualifications or experiences of the person being interviewed, and detailed questions on training, leadership and command structure, physical fitness, food, alcohol usage, medical support, health problems, tactical and operational problems, clothing and equipment and survival training.

Most of the population observed had lived their lives in a cold winter climate and 47% had received some previous form of cold weather military training. It was apparent that the cold was bothersome to most people, but not such a severe stress that they could not cope with it. Many persons who had never been exposed to severe cold (-30$^{\circ}$F) were apprehensive about their ability to perform and survive. This could be lessened by practice and training. Confidence was obtained rapidly with good instruction.

The sick call data showed the prevalence of minor disorders such as upper respiratory infections and muscular ailments over more severe problems such as cold injuries and fractures (See Table 1). Illnesses not reported to the medics were mainly for upper respiratory infections and muscular ailments, both not being severe enough to report to the medics. The overall treated illness/injury rate was approximately 4 percent. Although the incidence of major health problems was

low, the potential for serious consequences is very high with problems such as heart attacks, hypothermia, incapacitation and shock and major fractures. The best way to minimize such risks is with good preventive techniques and proper preparation in terms of having proper equipment on hand.

TABLE 1.

Rates for Sick Call for the Training Period

| | Rate/1000/2 wks | Rate/1000/day |
|---|---|---|
| Upper Respiratory Infections | 246.29 | 17.59 |
| Muscular Ailments | 149.07 | 10.65 |
| Orthopedic Injuries | 58.33 | 4.17 |
| Cold Injuries | 19.44 | 1.39 |
| Total | 473.13 | 33.80 |

While not directly evicenced in the sick call rates, the problem of overheating and alcohol drinking should be emphasized. Overheating was the most common problem observed during the study. This normally represented a tendency of people to overdress and not remove enough clothing before undertaking vigorous activity. This increases heat loss from the body and puts persons at risk for hypothermia and frostbite and prevents their clothing from later protecting them. The effect of alcohol on reaction time and coordination is severe enough to have a marked effect on injury rate.

The responses to the interiews were tabulated in 12 categories and represented the accumulated opinions of 29 people. Some of the more significant points will be rephrased here. People who have not lived or trained in low temperatures (-20°F and below) do not really understand the effects of cold on people and equipment. Having the proper "mental attitude" was most frequently mentioned as a requirement for people to do well in the cold. Physical conditioning was also frequently mentioned as being of special importance. Medics and troops must be taught life saving skills in the cold. Cold has a great tendency to cause deterioration in leadership. Leadership is difficult because everyone is interested

in his own survival. Having good leaders, particularly non-commissioned officers, at platoon and company level who know how to take care of their men will prevent most cold injuries. A major problem in the cold is keeping troops active. Activity is the key to warmth. People who panic in the cold do strange things. Be prepared for strange reactions in people who are afraid and panic. The 10-man tent group is the primary unit of cold weather operations.

Alcohol will be present in the field during an exercise. Commanders should be aware of it and make plans to control it. The major medical concern of line people was frostbite and how to deal with it. There was some confusion about the proper diet in the cold. People were unsure about the number of calories that should be consumed in the cold. A three day bivouac is a short time for people to learn to live in the field. For example, many people will put off personal hygiene measures until they can return to fixed facilities. Medical facilities should be located as close as possible to the troops because of difficulties involved with evacuation. Although the missions of the Army are the same in temperate and cold climates, the modus operandi in the cold may be different. The operations are slowed down and there is a different rhythm to activities. The most common complaint voiced was that the clothing was too heavy.

It was concluded that many improvements can be made to improve our state of readiness for winter warfare. An improved casualty evacuation system is needed. Medical force structures will need to be augmented. Improvements in vehicles and communications equipment are needed. "Hands on" training is needed for a unit to perform adequately in the cold. Future studies are needed on specific aspects of these problems. It would be useful to document the medical costs of cold weather training in terms of the true versus treated prevalence of cold-induced health problems and to have baseline data against which to judge future trends in these problems.

Future Plans:

Studies are needed to document the medical costs of cold weather training in terms of true versus treated prevalence of cold-induced health problems and to

have baseline against which to judge future trends in these problems. An epidemiologic evaluation of cold injuries is planned for the winter exercise, Empire Glacier, to be conducted in January 1978.

Presentations:

Current Concepts in Environmental (Climatic) Medicine Course, US Army Research Institute of Environmental Medicine, Natick, MA, May 1977.

Publications:

Behavioral Evaluation of a Winter Warfare Training Exercise, 1977. Technical Report (In preparation).

LITERATURE CITED

1. Hawryluk, O. Why Johnny Can't March: Cold Injuries and Other Ills on Peacetime Maneuvers. Military Medicine 142:377-379, 1977.

2. Young, M.B., R. E. Jackson, G. D. Bynum, D. L. Wolfe, L. M. Philo, C. R. Fay and D. O. White. A Study of Initial Treatment and Evacuation of Simulated Casualties in Cold Weather Environment. US Army Research Institute of Environmental Medicine, Technical Report No. 27/76, February 1976.

(83047)

| RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY | 1. AGENCY ACCESSION* | 2. DATE OF SUMMARY* | REPORT CONTROL SYMBOL |
|---|---|---|---|
| | DA OB 6147 | 77 10 01 | DD-DR&E(AR)636 |

| 3. DATE PREV SUM'RY | 4. KIND OF SUMMARY | 5. SUMMARY SCTY* | 6. WORK SECURITY* | 7. REGRADING* | 8a. DISB'N INSTR'N | 8b. SPECIFIC DATA-CONTRACTOR ACCESS | 9. LEVEL OF SUM |
|---|---|---|---|---|---|---|---|
| 77 06 15 | D. Change | U | U | NA | NL | ☒ YES ☐ NO | A. WORK UNIT |

| 10. NO./CODES:* | PROGRAM ELEMENT | PROJECT NUMBER | TASK AREA NUMBER | WORK UNIT NUMBER |
|---|---|---|---|---|
| a. PRIMARY | 6.27.77.A | 3E762777A845 | 00 | 047 |
| b. CONTRIBUTING | | | | |
| c. XXXXXXX | CARDS 114f | | | |

11. TITLE (Precede with Security Classification Code)*

(U)Improvement of Physical Fitness Training and Prevention of Injuries Related to Training(22)

12. SCIENTIFIC AND TECHNOLOGICAL AREAS*

012900 Physiology;012500 Personnel Training & Evaluation

| 13. START DATE | 14. ESTIMATED COMPLETION DATE | 15. FUNDING AGENCY | 16. PERFORMANCE METHOD |
|---|---|---|---|
| 76 10 | CONT | DA | C. In-House |

17. CONTRACT/GRANT

a. DATES/EFFECTIVE: EXPIRATION:

b. NUMBER:* NOT APPLICABLE

c. TYPE: d. AMOUNT:

e. KIND OF AWARD: f. CUM. AMT.

| 18. RESOURCES ESTIMATE | | a. PROFESSIONAL MAN YRS | b. FUNDS (In thousands) |
|---|---|---|---|
| FISCAL YEAR | PRECEDING 77 | 8.9 | 114 |
| | CURRENT 78 | 1.9 | 80.9 |

19. RESPONSIBLE DOD ORGANIZATION

NAME:* USA RSCH INST OF ENV MED

ADDRESS:* NATICK, MASSACHUSETTS 01760

RESPONSIBLE INDIVIDUAL

NAME: DANGERFIELD, HARRY G., M.D., COL, MC

TELEPHONE: 955-2811

20. PERFORMING ORGANIZATION

NAME:* USA RSCH INST OF ENV MED

ADDRESS:* NATICK, MASSACHUSETTS 01760

PRINCIPAL INVESTIGATOR (Furnish SSAN if U.S. Academic Institution)

NAME:* VOGEL, James A., Ph.D.

TELEPHONE: 955-2800

SOCIAL SECURITY ACCOUNT NUMBER:

ASSOCIATE INVESTIGATORS

NAME: DANIELS, William L., CPT, MSC

NAME: 955-2878 DA

21. GENERAL USE

Foreign Intelligence Not Considered

22. KEYWORDS (Precede EACH with Security Classification Code) (U)US Military Academy; (U)Physical Fitness; (U)Aerobic Power; (U)Psychological Inventories; (U)Submaximal Workload

23. TECHNICAL OBJECTIVE,* 24. APPROACH, 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)

23. (U)Army physical fitness training doctrine is based largely on outdated information and has been slow in adopting new scientific concepts. Physical training in the Army could be made more effective and efficient by appropriate research to meet the Army's needs with this new knowledge and obtain new information in specific areas relevant to the Army (women, older age) where information is lacking.

24. (U)Specific studies will include: (1) Determine the optimum mode, frequency, duration and intensity of training for different applications or needs; (2) Identify differences between men and women, if any, in the qualitative or quantitative response to training; (3) Establish suitable training programs for older age groups in the Army and (4) Document incidence of sports/training injuries and seek their prevention.

25. (U)76 10 - 77 09 A comparison of male and female responses to an identical intense basic military physical training program has just been completed. Random male and female plebes at the U.S. Military Academy were studies during their initial six weeks of basic training. Preliminary results suggests that women improved their aerobic fitness by 8% in this short period but did not achieve the high level possessed by men.

*Available to contractors upon originator's approval.

| | |
|---|---|
| Program Element: | 6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE |
| Project: | 3E762777A845 |
| Work Unit: | 047 Improvement of Physical Fitness Training and Prevention of Injuries Related to Training |
| Study Title: | Comparison of the Responses of Males and Females to an Identical Training Program |
| Investigators: | William L. Daniels, CPT, MSC, Ph.D. and Dennis M. Kowal, CPT, MSC, Ph.D. |

## Background:

A major requirement exists for the Army to establish a physical training program and fitness evaluation based on job and assignment irrespective of gender. Recent practical and research experience clearly indicates that previous female training programs did not met the needs of the present day female soldier (1). Old fitness standards and testing for females are outdated and unrealistic for the modern female soldier. A 1976 working symposium at the U.S. Army Infantry School pointed out the need for test events appropriate for both sexes and a scoring adjustment for women on these events (2).

In order to overcome these problems, field testing is being performed to evaluate integrated physical fitness training programs for male and female soldiers (3). However, the scientific basis for the establishment of such a program is lacking. Physiological differences in men and women as to their work capacity have been demonstrated (4), but it is generally believed that women have similar quantitative and qualitative responses to physical training. Most of the available literature, however, deals with studies that have been performed with athletes or women alone. There is a clear scientific and practical need to evaluate the response of young men and women to an identical, intense, military physical training program.

The objective of this study was to evaluate the physiological and related psychological responses of 18-22 year old men and women to the same Army basic physical training program.

The opportunity for this comparison was made available to us by the Office of Physical Education, US Military Academy in the form of a random sample of male and female cadets during their two months of basic training prior to the commencement of their first academic year.

The responses of the subjects to training were evaluated in terms of aerobic power, since it is the best measure of overall endurance capacity or stamina. The value of appropriateness of aerobic power, as measured by maximal oxygen uptake, as a measure of whole body endurance or cardiorespiratory fitness is well established (5).

However, aerobic power ($\dot{V}O_2$ max) is not the only measurement that provides information on endurance performance. Aerobic power defines the maximal capacity of the system to transport oxygen. At submaximal work loads, however, not all of the energy produced is derived from aerobic mechanisms. Some energy is produced by anaerobic mechanisms. How these anaerobic mechanisms are affected by training is not known. An additional purpose of this study was to collect information on anaerobic energy production at a fixed workload and to compare the effect of training on anaerobic energy production in men and women. This was done by measuring blood lactic acid at two submaximal work intensities.

Equally important in this study was an evaluation of the behavioral aspects in response to training. It is generally accepted that a significant portion of aerobic fitness is culturally determined. Attitudes toward activity, perception of effort and history of physical activity are suggested to be significantly different in men and women in the United States. A clearer understanding of these behavioral differences and how they are affected by an intense, coeducational training will be important in implementing a single tract physical training program in the Army. Behavioral questions addressed in this study were: a) the psychological "coping" mechanisms that are utilized by men and women to adapt to physically stressful conditions; b) changes in self-concept in men vs. women as a result of intensive, physical training; c) relative changes in attitude toward physical activity between men and women as a result of training; d) comparison of males and females perception of effort and fatigue as a result of training; and e) male-female comparison of changes in psychological well-being with physical training.

Progress:

Thirty male and female plebes, 18-22 years of age were randomly selected from the entering freshman class (July 1977) of the Military Academy and asked to volunteer to take part in this study during their first two months (July and August) of initial basic training prior to the start of the academic year. Both groups underwent an identical pre- and post-training evaluation. The pre-test took place during the week of arrival at the Academy. The post-test took place six weeks later, the second last week of basic training.

During the six week period of training, both groups participated in the same physical training program used for all entering plebes. The experimental subjects were not isolated but were integrated within their units of the entire class.

Body weight, to the nearest 100 gm, and height to the nearest 1 cm, was taken in shorts, T-shirt and stocking feet. Skin fold thickness was taken at four sites, subscapular, tricep, bicep and suprailiac, with a Harpendin caliper to estimate body density and thus calculate body fat content. The equations of Durnin and Womersley (6) were used.

$\dot{V}O_2$ max was determined using a modification of the interrupted treadmill running test described by Mitchell (7). Each subject performed two submaximal runs, after which, blood was drawn by venipuncture to measure lactate levels. Venipunctures were done 3-4 minutes after the end of each run. Each run was followed by a 5-10 minute rest period. At the end of the second rest period, additional runs of increasing severity were completed until $\dot{V}O_2$ no longer increased (less than 2 ml of $O_2$/kg/min increase with 2.0% or more grade increase). A plateau in $\dot{V}O_2$ with increasing work load was considered the $\dot{V}O_2$ max. There was a 5-10 minute rest period between each run.

$\dot{V}O_2$ and minute ventilation were measured from duplicate 20-30 second collections of expired air during the last minute of the run at each work load. Expired air was collected through a large mouthpiece and triple-J valve into vinyl Douglas bags. Expired air was analyzed with a Beckman E-2 oxygen analyzer and a Beckman LB-1 carbon dioxide analyzer. Expired air volumes were measured with a Tissot spirometer. Heart rate was recorded electrocardiographically.

A series of psychological inventories designed to measure transitory behavioral states and attitudes toward exercise and physical self was administered to the group. The following instruments inventories administered to each subject before and after the training period:

1. Spielberger State-Train Anxiety Inventory (STAI) - Estimates situational and enduring anxiety.

2. Profile of Mood States (POMS) evaluates tension, depression, anger, vigor, fatigue and confusion.

3. Physical Estimation and Attitude Scale (PEAS) - evaluates attitude toward physical activity and estimation of physical self.

4. Response to life problems - evaluates how individuals handle stress.

5. Personal History and Activity Questionnaire - provides demographic and background data. During exercise subjects were also asked to give a rating of their subjective effort in an attempt to predict physical work capacity in terms of the perceptual component as well as to determine the metabolic components which may serve as cues for these subjective reports of exertion.

During the week of 5-10 July 1977, subjects underwent the pre-training evaluation. Data obtained during the maximal work load is summarized in Table 1.

TABLE 1. Maximal Oxygen Uptake During Pre-Training Evaluation

| | $\dot{V}O_2$ max l/min | $\dot{V}O_2$ max ml/kg/min | Maximum HR | Max.Ventilation BTPS[a] | VEQ[b] |
|---|---|---|---|---|---|
| Men | 4.175 | 59.275 | 192.6 | 148.781 | 29.185 |
| +S.D. | $\pm$0.536 | $\pm$5.829 | $\pm$8.3 | $\pm$20.608 | $\pm$3.100 |
| Women | 2.658 | 45.926 | 186.3 | 99.992 | 30.885 |
| +S.D. | $\pm$0.336 | $\pm$5.138 | $\pm$18.6 | $\pm$15.337 | $\pm$4.628 |

[a] Body temperature and pressure, saturated; [b] Ventilatory equivalent

Data on submaximal work loads, body composition and blood lactates has not yet been completely analyzed and therefore is not contained in this report.

The post-training evaluation took place during the week of 16-23 August 1977. During this week 26 females and 29 males were re-tested. The only variable that we have analyzed at this time is $\dot{V}O_2$ max (ml/kg/min). Females showed approximately an 8% increase in $\dot{V}O_2$ max while males showed only a 1% increase.

The apparent discrepancy in the response of the males and females to training is probably due to the differences in their levels of cardiorespiratory fitness prior to the initiation of this training program. According to the American Heart Association's classifications of cardiorespiratory fitness (8), the females were within the "good" category; while the males had $\dot{V}O_2$ max values well above the level required for the "high" category. The men not only had numerically higher $\dot{V}O_2$ max levels but they also had relatively higher values when compared to standard tables for their age-sex group. Therefore, the males show little improvement in aerobic capacity because when they started the training program they were already at a high level of fitness. The females, on the other hand, showed substantial improvement and by the end of the training program they had increased in cardiorespiratory fitness from the "good" to the "high" category according to the standard table.

This very demanding physical training program was able to reduce the initial difference between the absolute aerobic power of men and women in the population studied.

<u>Presentations:</u>

None

<u>Publications:</u>

None

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8. Exercise Testing and Training of Apparently Healthy Individuals: A Handbook for Physicians. American Heart Association, 1972.

(83048)

| RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY | 1. AGENCY ACCESSION* | 2. DATE OF SUMMARY* | REPORT CONTROL SYMBOL |
|---|---|---|---|
| | DA OA 6123 | 77 10 01 | DD-DR&E(AR)636 |

| 3. DATE PREV SUM'RY | 4. KIND OF SUMMARY | 5. SUMMARY SCTY* | 6. WORK SECURITY* | 7. REGRADING* | 8a. DISB'N INSTR'N | 8b. SPECIFIC DATA-CONTRACTOR ACCESS | 9. LEVEL OF SUM |
|---|---|---|---|---|---|---|---|
| 77 09 02 | D. Change | U | U | NA | NL | [X] YES [ ] NO | A. WORK UNIT |

| 10. NO./CODES:* | PROGRAM ELEMENT | PROJECT NUMBER | TASK AREA NUMBER | WORK UNIT NUMBER |
|---|---|---|---|---|
| a. PRIMARY | 6.27.77.A | 3E762777A845 | 00 | 048 |
| b. CONTRIBUTING | | | | |
| XXXXXXXX | CARDS 114f | | | |

11. TITLE (Precede with Security Classification Code)* (U) Biomedical Impact of Military Clothing and Equipment Design Including the Selection of Crew Compartment Environments (22)

12. SCIENTIFIC AND TECHNOLOGICAL AREAS*
013300 Protective Equipment; 022400 Bioengineering

| 13. START DATE | 14. ESTIMATED COMPLETION DATE | 15. FUNDING AGENCY | 16. PERFORMANCE METHOD |
|---|---|---|---|
| 64 01 | CONT | DA | C. In-House |

17. CONTRACT/GRANT

a. DATES/EFFECTIVE: EXPIRATION:
b. NUMBER:* NOT APPLICABLE
c. TYPE: d. AMOUNT:
e. KIND OF AWARD: f. CUM. AMT.

| 18. RESOURCES ESTIMATE | | a. PROFESSIONAL MAN YRS | b. FUNDS (In thousands) |
|---|---|---|---|
| FISCAL YEAR | PRECEDING 77 | 8. | 298 |
| | CURRENT 78 | 8. | 354.7 |

19. RESPONSIBLE DOD ORGANIZATION

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TELEPHONE: 955-2811

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TELEPHONE: 955-2831
SOCIAL SECURITY ACCOUNT NUMBER:

ASSOCIATE INVESTIGATORS
NAME: BRECKENRIDGE, John R.
NAME: 955-2833 DA

21. GENERAL USE
Foreign Intelligence Not Considered

22. KEYWORDS (Precede EACH with Security Classification Code) (U)Tolerance Prediction; (U)Protection; (U)Biophysics; (U) Thermal Exchange; (U)Insulation(clo); (U)Evaporative Cooling Index; (U)Moisture Permeability Index

23. TECHNICAL OBJECTIVE,* 24. APPROACH, 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)

23. (U)Study energy exchanges in the Man-Clothing-Environment system, to provide a basis for improving thermal protection and recommending crew environments in military vehicles.

24. (U)Analyses of materials, uniforms and/or equipment using heated "sweating" flat plates, manikins, etc. indicate their effects on heat and moisture exchange and aid in predicting the user's physiological responses. Results provide guidance for military designers and identify stressful items or environments. Findings may be verified on soldiers in chamber or field studies.

25. (U)76 10 - 77 09 A long-term study to establish design requirements for maximizing effectiveness of reflective layers in cold weather clothing was completed. Results suggest that, at best, reflective layers increase insulation of handwear and footwear by 8%, and of clothing ensembles by 10%. Insulation measurements, in support of DARCOM developments, were made on numerous civilian and military ensembles, handwear and footwear items, and sleeping bags; quality control checks of heat leakage patterns, using an AGA infrared camera were also made on current production military bags. Studies for the Navy and Air Force of anti-immersion suits were continued. Insulating and evaporative transfer characteristics of NATO fabrics, CW clothing and casualty bags, were determined. In collaboration with DARCOM developers, LEAA, FBI and the State of California, Kevlar body armor was studied to (1) assess its impact on heat stress and (2) establish design criteria for controlling moisture uptake during wear (excess water destroys its ballistic effectiveness); water uptake measured on the "sweating" manikin agreed closely with that measured after wear by active police personnel. Consultation services on various aspects of thermal protection were also provided various US military and civilian agencies.

*Available to contractors upon originator's approval

DD FORM 1 MAR 68 1498 PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE. DD FORMS 1498A, 1 NOV 65 AND 1498-1, 1 MAR 68 (FOR ARMY USE) ARE OBSOLETE.



* U.S. GPO: 1974-540-843/8691

Program Element: 6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE

Project: 3E762777AB45 Environmental Stress, Physical Fitness and Medical Factors in Military Performance

Work Unit 048: Biomedical Impact of Military Clothing and Equipment Design, Including the Selection of Crew Compartment Environments

## Introduction

Systematic study of thermal exchange between man and his environment, as modified by his clothing and equipment, has been conducted continuously over a span of many years. The aim of this program has been to reduce environmental injuries and degradation of military performance by insuring that the soldier is provided with the best possible protection in extreme hot and cold environments. This is accomplished by working with problem areas surfaced by the user, or working with the developer during development to recommend changes in personal equipment design and/or tactical doctrine to eliminate, insofar as possible, imbalances between heat gains at the skin from metabolic processes and solar heating, and heat losses permitted by the clothing. Two parameters of clothing, namely (a) its insulation or clo value (1) and (b) its evaporative cooling index $i_m$/clo, where $i_m$ is Woodcock's moisture permeability index (2), are sufficient to suggest the environmental range over which balance may be maintained for a given heat dissipation requirement, i.e., metabolic plus solar heat load. Outside this range, these two parameters are essential for predicting how long the soldier can perform before (a) becoming inefficient or (b) reaching physiological tolerance limits. Measurements to define these two, and how they could be modified by a "pumping coefficient" to reflect changes with body and air motion, have been systematically made on many types of materials, uniforms, handwear, footwear and personal equipment, alone and in combination, using heated "sweating" flat plates, manikins, and sectional hands and feet. Results of studies can be interpreted for medical implications with respect to environmental injuries, for tactical implications with respect to tolerance limits and mission performance degradation, and for

clothing designers in terms of the impact on the soldier in the field. Various advanced technology methods of increasing heat loss to reduce stress in hot environments (such as clothing ventilation and/or air conditioning systems), and for decreasing heat loss in the cold through use of auxiliary heat sources, have been evaluated in terms of the increased tolerance under a given set of activity/equipment/environment conditions.

Studies have concurrently been conducted to determine the effects of various clothing design factors such as size, fabric flexibility, location of windproof layers and closures, etc., on the changes in clo and $i_m$/clo, with and without air motion from wind or body motion; this research has led to the concept of the "pumping coefficient" cited above. Mathematical models based on physical principles have also been developed to describe the effects of laundering, increased insulation weight, and such factors as moisture in the clothing. Such an understanding of clothing protection principles is required to permit intelligent interpretation of experimental measurements on clothing systems, to provide a basis for recommending design changes and to identify appropriate, but safe, conditions for subsequent physiological trials in climatic chambers or in the field. Such expertise is also useful in suggesting modified tactics and operational procedures for troop commanders to avoid unacceptable levels of environmental casualties during operations involving extremes of heat or cold stress. These models of physical clothing and environmental factors, in combination with activity data and physiological characteristics derived under another work unit (053), are also used to specify the ideal, as well as the tolerance-limiting, environments for crew compartments in military vehicles or aircraft; these data are extremely useful during the initial design stages of a vehicle, and, at present, also have to be used to specify environmental modifications required for troop effectiveness in existing vehicles.

The copper manikin, developed by the U. S. Army and used in these studies, was constructed to the size of an average U. S. Army infantryman; as such he wears standard (medium, regular) uniforms. The manikin is hollow; inside his "skin" are three electrical components: 1) heating wires -- to deliver heat to his copper skin, 2) thermocouples -- to measure the temperature at 19 representative sites on his skin, and 3) a thermostat -- to control the power delivered to the heaters.

In use, the desired skin temperature is maintained by delivering electrical power to the heating wires. If the number of watts of heat required to maintain a constant skin temperature is measured, this amount of heat must exactly equal the heat lost from the skin, since otherwise skin temperature would change. This heat loss is a direct measure of the insulation provided by clothing or equipment worn by the manikin. This technique is used to measure the insulation ("clo" index) of sleeping bags and cold weather or other uniforms in which the soldier does not usually sweat. If a cotton "skin" is used to cover the manikin and wetted, the extent to which a uniform interferes with evaporative cooling ("sweating") can be measured (permeability index - $i_m$).

The studies under this work unit seldom result in publications from the individual studies; instead the results are presented in DF reports, MFRs and at innumerable briefings. The information gathered is, of course, the essential information base from which we are able to provide the many consultations on tolerance times in extreme environments, operational performance degradations, and the like, for which we serve as a source of expertise.

## LITERATURE CITED


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2. Woodcock, A. H. Moisture transfer in textile systems, Part I. Text. Res. J., 32:628-633, 1962.

## I. STUDIES ON SLEEPING SYSTEMS

### Background:

A soldier of average size produces approximately 72 kcal/hr while sleeping. About 25% of this leaves the body from respiration and evaporation from the skin, leaving 75% (54 kcal/hr) to be lost by radiation and convection.

Two definitions can be used for "adequacy" of a cold weather sleeping system: (a) "Comfort", which implies that a sleeping soldier loses just 54 kcal/hr; or (b) "6 hours rest" which allows him to incur a body heat debt of 80 kcal during 6 hours of sleep, and therefore to lose (54 + 80/6) or 67.3 kcal/hr. If skin temperature asleep is comfortable (i.e., not below an average value of 32°C), then the lowest temperature for "comfort" is $Ta_{min} = 32 - 5.4 \times clo$ where clo is the insulation value of the sleeping bag; for the "6 hours rest" criterion, $Ta_{min} = 32 - 6.7 \times clo$. The following table relates the insulation provided by a sleeping system to the minimum air temperatures for these two criteria.

TABLE 1

| Insulation (clo) | Example of System | "COMFORT" (°C) | 6 hrs REST (°C) |
|---|---|---|---|
| | Sleeping Bags on Ground | | |
| 4 | Synthetic (dacron fill) | 10.4 | 5.1 |
| 5 | "Mountain" 60/40 chicken feather and down fill | 5.0 | -1.6 |
| 6 | Commercial:100% prime goose | -0.4 | -8.4 |
| 7 | "Inter. Cold" poly; 60/40 outer channels | -5.8 | -15.1 |
| 8 | "Extreme Cold" poly:100% down outer | -11.2 | -21.8 |
| | Sleeping Bags & Additions | | |
| 9 | "Extreme Cold above + insulated pad, clothing, hood & poncho liner | -16.6 | -28.6 |
| 10 | All 9 clo above + warm gloves & booties | -22.0 | -35.3 |
| Above 10 | Not achieved - auxiliary heat? | -27.4 | -42.0 |

One can relate the required insulation to avoid cooling while asleep to the VII climatic zones specified for Army RDT and E, simply from the heat loss limitation that must be imposed to match the man's sleeping heat production. As shown in the figure below, prevention of cooling while asleep requires ~12 clo of insulation at $-40^{\circ}C$, while ~10 clo is required to meet the usual specification that a bag shall allow 6 hours of restful sleep at $-40^{\circ}C$. This specification has never yet been met by any any Arctic bag.

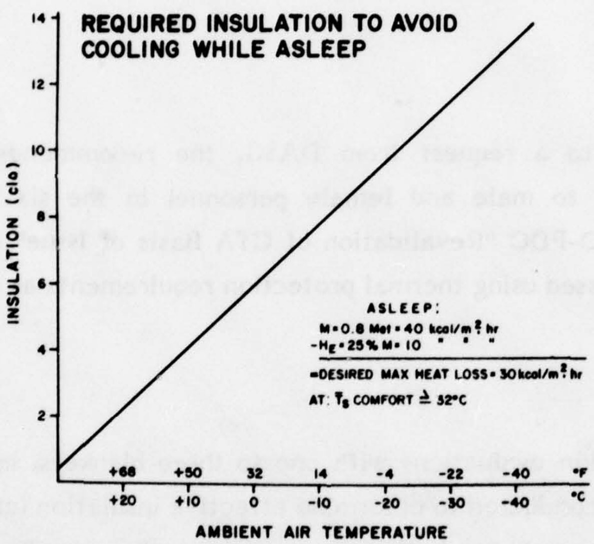


Figure 1. Required insulation to avoid cooling while asleep; mean skin temperature assumed normal ($32^{\circ}C$)

| | |
|---|---|
| Program Element: | 61.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE |
| Project: | 3E762777AB45 Environmental Stress, Physical Fitness and Medical Factors in Military Performance |
| Work Unit: | 048 Biomedical Impact of Military Clothing and Equipment Design Including the Selection of Crew Compartment Environments |
| Study Title: | Insulation Afforded by Blankets |
| Investigators: | Onofrio Compagnone, Ralph F. Goldman, Ph.D., John R. Breckenridge |

## Background:

In response to a request from DASG, the recommended allowances for blankets for issue to male and female personnel in the six climatic zones as requested in DAMO-FDO "Revalidation of CTA Basis of Issue" dated 8 November 1976 has been assessed using thermal protection requirements as a criterion.

## Progress:

Copper manikin evaluations with one to three blankets, in a bed and on the ground, have been conducted to determine effective insulation (clo) values. Results of these measurements and the corresponding "comfort" temperatures are summarized below:

Insulation with one to three blankets and predicted lower "comfort" temperatures:

| State | Insulation[a] (clo) | Heat Loss kcal/m$^2$hr $^\circ$C | Comfortable to |
|---|---|---|---|
| In bed | | | |
| sheets only | 2.2 | 2.5 | 20$^\circ$C |
| one blanket | 3.1 | 1.8 | 15$^\circ$C |
| two blankets | 3.8 | 1.5 | 12$^\circ$C |
| three blankets | 4.3 | 1.3 | 9$^\circ$C |

| | | | |
|---|---|---|---|
| On Ground[b] | | | |
| one blanket | 2.6 | 2.1 | $18^{\circ}C$ |
| two blankets | 3.6 | 1.5 | $13^{\circ}C$ |
| three blankets | 4.6 | 1.2 | $7^{\circ}C$ |

b - Manikin wrapped in blankets, no ground cloth or sleeping pad.

a - Clo values ranging from 0.3 to 0.9 clo higher were obtained in bed with the manikin head covered; these higher values should produce comfort at temperatures up to $5^{\circ}C$ lower than indicated. All on-ground measurements were made with feet and head covered.

From these results, a realistic basis of issue for the various zones was specified. For Zones III and IV ($32^{\circ}F$), it was predicted that at least 5 blankets would be required on the ground for comfort. The present CTA was therefore considered an arbitrary choice with little reference to actual climatic zone temperatures.

A Memorandum summarizing these findings and recommendations has been transmitted by 1st Indorsement CO, USARIEM to HQDA(DASG-HCO-O/Ms. L. Nearing).

**Presentations:**

None

**Publications:**

None

| | |
|---|---|
| Program Element: | 6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE |
| Project: | 3E762777AB45 Environmental Stress, Physical Fitness and Medical Factors in Military Performance |
| Work Unit: | 048 Biomedical Impact of Military Clothing and Equipment Design Including the Selection of Crew Compartment Environments |
| Study Title: | Gound Insulation for Sleeping Systems |
| Investigators: | Onofrio Compagnone, Ralph F. Goldman, Ph.D., John R. Breckenridge |

Background:

Although extensive information on sleeping bag insulation and the effects of various insulating pads is available, there is little or no information on insulation afforded while sleeping on soft vs. compacted vs. frozen ground, with or without ground beds of leaves or pine boughs, or on loose or compacted snow. Such results would be of significance in terms of Army survival doctrine.

Progress:

A copper manikin investigation was conducted to determine the feasibility of using naturally occurring materials such as pine boughs, leaves, or snow in place of an inflatable pad under a sleeping bag in an emergency situation. Insulation measurements were made over a frozen earth bed, with the manikin (dressed in standard winter underwear plus wool socks) in an extreme cold LINCLOE sleeping bag. Results of the study are presented in Table 1.

TABLE 1

Insulation Values with Various Types of Ground Cover under LINCLOE Bag

| Layer Between Bag and Frozen Earth | Total Insulation: Ground Cover Only | Total Insulation: Std Insulated Pad Added |
|---|---|---|
| 1. None | 5.7 | 6.8 |
| 2. 4 inches of pine boughs | 5.9 | 6.9 |
| 3. 4 inches of leaves (sprayed with water) | 6.5 | 7.1 |
| 4. Newspapers | | |
| 1/8 inch thickness | 6.2 | |
| 1/4 inch thickness | 6.7 | |
| 1 inch thickness | 7.1 | |
| 1 inch thickness, wet | 6.9 | |
| 5. 6 inches of snow on earth | | |
| fresh snow | 5.8 | 7.0 |
| wet snow | 5.5 | |
| plus pine boughs | 5.9 | |
| plus 1/2 inch of newspapers | 7.0 | |

These results indicate that naturally-occurring ground covers increased insulating effectiveness of the Extreme Cold Lincloe bag from 0.2 to 0.8 clo, while a standard insulated pad (used in conjunction with ground cover) added approximately 1 clo. A 4-inch leaf bed was the most effective (0.8 clo increase over the 5.7 clo measured with no ground cover). Surprisingly, a 6-inch snow cover provided only marginal improvement over sleeping on bare ground. This probably was due to the fact that the bottom surface of the bag was near freezing temperature, causing some snow melting and perhaps wetting of the underside of the bag.

Data showing the effectiveness of newspapers as a ground cover are included in the table for comparison purposes. Newspapers are not naturally occurring, nor would they normally be available in an emergency situation. However, they obviously provide excellent insulation and would serve well as a temporary ground cover. A 1/4" layer of newspapers under the Lincloe bag produced an overall clo value of 6.7 clo, or 0.2 clo more than 4 inches of leaves. One inch of newspapers

raised the clo value to 7.1, the same as 4 inches of leaves plus an insulated pad.

In a second phase, the insulation afforded by the foam pads which have captured the civilian market for ground cover under sleeping systems and almost totally eliminated air mattresses, were evaluated with a view to achieving the goal of the 10 clo of insulation which would provide 6 hours of restful sleep at -35°C. The results for a prototype extreme cold LINCLOE bag, which incorporated only synthetic materials and feather insulation, and for the extreme cold LINCLOE bag incorporating 1.4 lbs of down, eventually Type Classified, are given below:

TABLE 2

Insulation afforded by foam sleeping pads (ensolite flexible at -40°C) cut to standard pad dimensions

Series A Sleeping bag B-II-2 Premodified LINCLOE extreme cold, large size, approx. 9.5 lbs.

| Base | Insulation(clo) |
|---|---|
| Bare floor (concrete) | 5.70 |
| Standard air mattress | 6.23 |
| Insulated standard air mattress | 7.31 |
| Ensolite foam, 3/8 inch | 6.88 |
| Ensolite foam, 1/2 inch | 7.10 |
| Ensolite foam, 3/4 inch | 7.49 |
| Ensolite foam, 1 inch | 7.72 |
| Ensolite foam, 2 inch | 8.74 |

Series B - Sleeping Bag B-II-5 Modified LINCLOE extreme cold, (adopted as STND), 9.5 lbs but 1.4 lbs of down substituted for feather mixture.

| Base | Insulation(clo) |
|---|---|
| Standard air mattress | 6.91 |
| Insulated air mattress | 8.06 |
| Ensolite foam, 3/8 inch | 7.91 |
| Ensolite foam, 1 inch | 8.75 |
| Ensolite foam, 2 inch | 9.89 |
| Ensolite foam, 3 inch | 10.42 |

These results show that the addition of the down was extremely beneficial, that the insulated air mattress is substantially warmer than the uninsulated version, and that a 3/8" foam pad provides a bit less insulation than the insulated air mattress. While 10 clo was achieved, the 2 to 3 inch thickness of foam required is obviously impractical.

Future Plans:

Study completed. New approaches to underbag protection will be investigated under separate studies.

Presentations:

None

Publications:

None

| | |
|---|---|
| Program Element: | 6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE |
| Project: | 3E762777AB45 Environmental Stress, Physical Fitness and Medical Factors in Military Performance |
| Work Unit: | 048 Biomedical Impact of Military Clothing and Equipment Design Including the Selection of Crew Compartment Environments |
| Study Title: | (1) Evaluation of Current Production Standard LINCLOE Sleeping Bags and Air Mattresses and (2) Evaluation of New and Laundered Experimental and Current Production Sleeping Bags |
| Investigators: | Onofrio Compagnone, Ralph F. Goldman, Ph.D., John R. Breckenridge |

## Background:

The Defense Personnel Support Center is procuring a quantity of insulated pneumatic mattresses for military use. A resin treated polyester batting was used inside the mattresses to provide additional insulation from the ground. To insure that the construction was correct and the insulating characteristics were maintained on this mass production procurement item, a physiological evaluation was required using the standard LINCLOE Intermediate and Extreme Cold Bags. At the same time, tests were required of the regular pneumatic mattresses as a comparison. These two sleeping bags, as well as earlier pneumatic mattresses, had previously been evaluated, but a quantity of LINCLOE bags of both types are presently being attained in accordance with procuring documents. Uniformity in placement of the insulation was questionable; thus, it was imperative that an evaluation be made prior to large scale procurements of these bags.

## Progress:

The insulation (clo) values of the standard and new production sleeping bags, as measured with the single circuit copper man, are shown in Table 1.

TABLE 1

Comparison of Insulation Values (Clo) for Intermediate and Extreme Cold LINCLOE Sleeping Bags with Pneumatic Mattresses

| Sleeping Bags | Control Mattresses | | New Production Mattresses | |
|---|---|---|---|---|
| | Non-Insulated Mfd 1969 | Insulated Mfd 1970 | Non-Insulated Mfd 1975-6 | Insulated Mfd 1975-6 |
| Std. Intermed. Cold | | | | |
| Control | | | | |
| #B-I-2 | 5.5 | 6.3 | 5.4 | 6.1 |
| ( wt.=3.4 kg) | | | | |
| Current Production | | | | |
| (wt.=3.6 kg) | 5.3 | 5.7 | 5.3 | 5.7 |
| Std. Extreme Cold | | | | |
| Control | | | | |
| #B-II-5 | 7.3 | 8.2 | 7.4 | 7.9 |
| (wt.=4.4 kg) | | | | |
| Current Production | | | | |
| (wt.=4.0 kg) | 5.9 | 6.2 | 5.9 | 6.6 |
| (wt.=4.4 kg) | 6.6 | 7.2 | 6.7 | 6.9 |

These values compare the respective current production Intermediate Cold and Extreme Cold sleeping systems with their older (our control) counterparts. They indicate that, in the case of the Intermediate Cold Bag, there were only very slight differences, which however, are repeated when comparing clo values using the various insulated and non-insulated mattresses. While these differences are small, they occur in the same direction, i.e., slightly less insulation with the current production bags and a more marked decrease with the insulated pads. Using our recommended NATO draft STANAG criterion that the lowest ambient comfortable temperature (i.e., no heat debt while asleep) is $32^{o}C - 5.4 \times clo$, a decrease in insulation of from 0.1 to 0.6 clo would increase the "comfortable" ambient temperature by from 0.5 to $3^{o}C$ ($1^{o}$ to $6^{o}F$).

When comparing clo values of the two new production Extreme Cold bags with the original standard bag #B-II-5 (our control standard LINCLOE Extreme Cold

bag), there are significantly large differences. i.e. a 2 clo difference between B-II-5 (8.2) and the 6.2 clo for one of the new bags when both bags were tested with the same 1970 standard air mattress. This reduction in insulation for the new bag effectively increases the "comfortable" ambient temperature by 10.5°C (19°F), a serious decrease in protection.

It was thought that the 8.2 clo of insulation of our control bag (#B-II-5) may have resulted because it was locally constructed at NARADCOM using the very best materials and expert workmanship. In addition, bag B-II-5 had been carefully stored and never subjected to the same compression force that the current production bags endured prior to arrival at Natick from the manufacturer. We therefore ran additional tests after first rolling and tightly tying B-II-5 and then storing it for 10 days beneath the combined weight of a number of other rolled up bags. Subsequent measurements showed that the insulation values were unchanged by this compressed storage. We can only conclude that the differences in clo between the new production Extreme Cold bags and bag #B-II-5 reflect primarily differences in the quality, quantity, and/or distribution of the down and other insulating materials used in the bags and/or in their fabrication. One of the current production bags manufactured by one manufacturer appears significantly worse than that produced by the other.

In addition to evaluation of current bag production, as discussed above, current production underpads were also evaluated. Clo values comparing the new production air mattresses with our standard reference are given in Table 2.

TABLE 2

Comparison of Current Production Sleeping Pad Insulation Values with Standard Reference Values ("clo" insulaion) when Used Under Standard Sleeping Bags

| Pneumatic Mattresses | Sleeping Bags | | | | |
|---|---|---|---|---|---|
| | Controls | | Current Production | | |
| | Intermediate Cold #MM3 (Mfd 1969) | Extreme Cold B-II-5 (Mfd 1970) | Intermediate Cold (Mfd 1975) | Extreme Cold (Mfd 1975) | Extreme Cold 767 (Mfd 1975-6) |
| Non-Insulated | | | | | |
| Control | | | | | |
| Mfd 1969 | 5.5 | 7.3 | 5.3 | 5.9 | 6.6 |
| Current Production | | | | | |
| Mfd 1975 | 5.5 | 7.4 | 5.3 | 5.9 | 6.7 |
| Insulated | | | | | |
| Control | | | | | |
| Mfd 1969 | 6.3 | 8.3 | 5.7 | 6.2 | 7.2 |
| Current Production | | | | | |
| Mfd 1975 | 6.2 | 7.9 | 5.9 | 6.6 | 6.9 |
| Mfd 1975 | 6.0 | 7.8 | 5.8 | 6.6 | 7.0 |

**These results clearly demonstrate that the heat transfer characteristics of the current-production pads are essentially identical to those of previous years.**

**Presentations:**

None

**Publications:**

None

| | |
|---|---|
| Program Element: | 6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE |
| Project: | 3E762777AB45 Environmental Stress, Physical Fitness and Medical Factors in Military Performance |
| Work Unit: | 048 Biomedical Impact of Military Clothing and Equipment Design Including the Selection of Crew Compartment Environments |
| Study Title: | Evaluation of UK Sleeping Systems and Evaluation of French and other NATO Sleeping Bags |
| Investigators: | Onofrio Compagnone, Ralph F. Goldman, Ph.D., John R. Breckenridge |

Background:

In connection with US interest in implementing a NATO Standardization Agreement (STANAG) prescribing uniform methods for physical and physiological testing of clothing and personal equipment, sleeping bag systems furnished by NATO member nations have been evaluated with the copper man.

Progress:

Insulating (clo) values of the NATO items furnished are given in Table 1, along with results for several U.S. military sytems. These results were presented and discussed at the 1977 meeting of the NATO Combat Clothing and Equipment Working Party.

The best available U.S. commercial all down bags were also evaluated so that our analysis could include commercial as well as military developments. The values measured for 6 all-down bags are shown in Table 2.

TABLE I
Insulation of Various NATO and Other Sleeping Bags as
Measured with Copper Man

| No.[a] | Country | WEIGHTS Fill (Kg) | WEIGHTS Total (Kg) | INSULATION VALUE No pad, bare floor (clo) | INSULATION VALUE Own pad, if any (clo) |
|---|---|---|---|---|---|
| | Australia | | 2.6 | 2.9 | 3.4 |
| | Belgian | | | | |
| 1 | "Synthetique" | | 1.7 | 3.8 | |
| 2 | "Duvet" | | 1.4 | 4.7 | |
| | Canada | | | | |
| 3 | Inner | | 2.1 | 5.2 | 6.3 |
| 4 | Outer | | 2.7 | 4.3 | 5.7 |
| | Both | | 4.8 | 7.3 | 9.0 |
| | AF Survival | | 2.8 | 5.0 | |
| | Denmark | | | | |
| | None Received | | - | - | - |
| 5 | France | | 2.9 | 3.2 | |
| 6 | Germany | | 3.0 | 3.6 | |
| 7 | Greece | | 2.3 | 3.2 | |
| 8 | Italy | | 3.1 | 5.8 | |
| 9 | Netherlands | | 3.7 | 3.3 | |
| 10 | Norway | | 4.0 | 4.3 | 5.3 |
| | Portugal | | | | |
| | None Received | | - | - | - |
| | U.K. | | | | |
| 11 | Moderate cold | | 3.3 | 4.9 | 5.4 |
| 12 | Extreme cold | | 4.8 | 6.9 | 8.0 |
| | U.S. | | | | |
| | "LINCLOE" | | | | |
| 13 | Intermed. cold | 1.7 | 3.4 | 5.8 | |
| 14 | Extreme cold | 2.2 | 4.3 | 7.8 | |
| 15 | Mountain (Std B) | 1.4 | 3.8 | 5.1 | 5.4 |
| | Arctic (Std B) | 2.6 | 6.4 | | 7.3 |
| | Std Cas. Evac. | 3.6 | 7.1 | 5.8 | |
| | Army Aircrew Survival | .5 | 2.0 | 4.2 | |
| | A.F. Walk-Around Survival | 1.7 | 3.4 | 5.3 | |

a-Point designation in Figure 1.

TABLE 2

U.S. Commercial All Down Sleeping Bags*

| | INSULATION (clo) Bare Ground | WEIGHT (kg) Fill | Total |
|---|---|---|---|
| Duck Down | 6.6 | 1.1 | 2.0 |
| Goose Down | 6.6 | 1.1 | 2.2 |
| Duck Down | 7.9 | 1.5 | 2.6 |
| Goose Down | 8.0 | 1.4 | 2.7 |
| Duck Down | 8.3 | 1.6 | 2.7 |
| Goose Down | 7.6 | 1.5 | 2.9 |

*All values measured with face closure clipped

Results were interpreted in terms of heat loss and duration of protection for member nations using the relation of insulation to bag weight as plotted in the figure below.

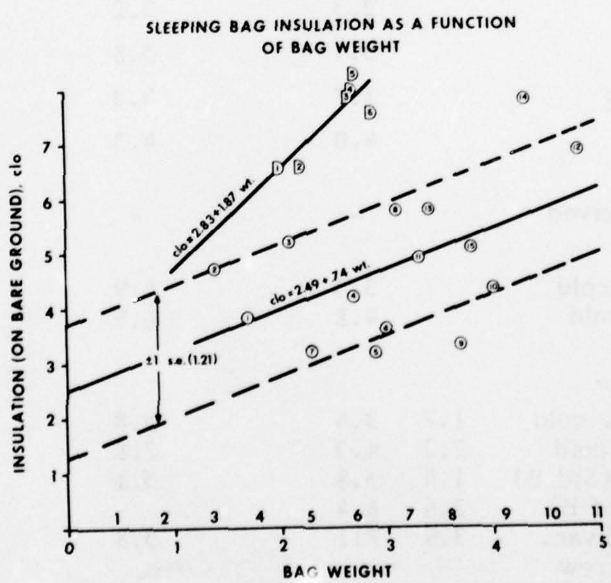


**Figure 1. Insulation value as a function of bag weight for polyester-filled NATO and U.S. military bags, and commercial down-filled bags (upper line)**

The points for the various bags fell into two groups, one for polyester-filled bags as typified by the NATO and U.S. military bags, with an insulating (clo) value-weight locus expressed by:

$$\text{clo} = 2.49 + 0.74 \text{ weight (in kg)}$$

and the other for down-filled bags D-1 to D-6 with superior characteristics given by:

$$\text{clo} = 2.83 + 1.87 \text{ weight (in kg)}$$

Efficiency of each bag could be judged from this figure by noting the extent to which the point for the bag fell above or below the line applying to that class of bag. Bag 2, Belgian "Duvet" initially appeared an excellent example of a polyester bag; on later examination, however, it turned out to be an over-filled down bag, which made it less efficient for its weight than the commercial U.S. down bags; i.e., its point fell below the projected locus for a down bag of that weight.

Additional NATO sleeping systems will be evaluated for member nations as they are submitted.

Presentations:

Breckenridge, J. R., O. F. Compagnone, and R. F. Goldman. Characterization of protective insulation of sleeping systems. Combat Clothing and Equipment Working Party, NATO, Brussels, Belgium, 6-10 June 1977.

Publications:

None

| | |
|---|---|
| Program Element: | 6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE |
| Project: | 3E762777AB45 Environmental Stress, Physical Fitness and Medical Factors in Military Performance |
| Work Unit: | 048 Biomedical Impact of Military Clothing and Equipment Design Including the Selection of Crew Compartment Environments |
| Study Title: | Evaluations of "Defective" Production Run Sleeping Bags of the Mountain (M-1949) Std B Sleeping Bags |
| Investigators: | Clement A. Levell, Onofrio Compagnone, John R. Breckenridge |

Background:

Complaints from the field led to a question of the thermal insulation provided a sleeping soldier by current production runs of the M-1949 Mountain Sleeping Bag (Std B). Accordingly, the developer requested that we conduct an evaluation of the physiological effects of use of these suspect bags.

Progress:

Quality control checks were determined for four current-production M-1949 sleeping bags suspected of providing inadequate protection. These bags were measured for insulation value using the copper manikin and also studied for localized cooling (due to uneven filling) using an AGA thermovision camera. Several sites were found where elevations in surface temperature, up to 3°C, indicated very poor local insulation value. Despite this, the manikin measurements of overall clo value did not indicate any reduction below our usual value for M-1949 bags, (5.7 clo) except for one bag which measured ~5% less. The insulation voids in the channels were easily eliminated by employing a bag-beating procedure to insure even fill distribution. Values, after beating the bags, ranged from 5.5 to 5.8 clo, which are considered acceptable; the bag which measured 5% low (5.39 clo) measured 5.57 after extensive beating to redistribute the insulation.

**Presentations:**

None

**Publications:**

None

| | |
|---|---|
| Program Element: | 6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE |
| Project: | 3E762777AB45 Environmental Stress, Physical Fitness and Medical Factors in Military Performance |
| Work Unit: | 048 Biomedical Impact of Military Clothing and Equipment Design Including the Selection of Crew Compartment Environments |
| Study Title: | Insulation Evaluation of a Commercially Available (Foreign) Electrically Heated Campers' Sleeping Bag |
| Investigators: | George F. Fonseca, M.S., Onofrio Compagnone, Ralph F. Goldman, Ph.D. |

## Background:

As part of the evaluation of electrical heating applications for their military potential, both single circuit and sectional copper manikin evaluations of a Dutch sleeping bag incorporating auxiliary heating, were performed.

## Progress:

Single circuit manikin insulation values (clo) for various combinations of head and face cover are shown in Table 1.

TABLE 1
Single Circuit Copper Man Evaluation of #600 Sleeping Bag, Without Auxiliary Heat

| | Insulation Value (Clo) On Bare Floor | Insulation Value (Clo) On STD Insulated Pad |
|---|---|---|
| 1. Bag #600, w/4 clips to close face/head opening; stuff sack w/built-in pad used for head-rest; no other head cover. | 2.3 | 2.7 |

| | | | |
|---|---|---|---|
| II. | As above, with single layer of cloth to cover head/face area previously exposed. | 3.1 | - |
| III. | As above, with two layers of cloth to cover head/face area[a] | 3.4 | 3.7 |

a - Head cover used to provide more uniformity between uncovered head temperatures and adjacent area temperatures; two layers proved necessary.

The basic insulation (2.3 clo) value suggests that this 1.8 kg (4 lb) bag, as constructed (29"w x 78" l), is not practical for use in other than a mild temperature (15$^{o}$C) without auxiliary heat. An improvement to the 3.7 clo value level was accomplished by adding the standard insulated pneumatic mattress and a layer of blanket cloth material to cover the exposed face and head area. The value of 3.4 clo on the bare floor approaches the measured insulation value of the Belgian "Synthetique" bag, which weighs 1.7 kg and provides 3.8 clo of insulation.

Next, the heating effect on the sectional manikin was evaluated when either 12 volts or 24 volts DC was applied to the heating element of the electrically heated sleeping bag (Table 2). The sectional and total clo values without auxiliary heat supplied to this sleeping bag are also shown:

TABLE 2
Sectional and Total Clo Values for the Electrically Heated Sleeping Bag (Chamber air temperature = 0$^{o}$F (-17.8$^{o}$C)

| Manikin Sections | Unheated | Electrically Heated 30 watts[a] | 49 watts[b] |
|---|---|---|---|
| Head | 1.7[c] | 2.0 | 2.1 |
| Torso | 5.4 | 5.6 | 5.8 |
| Arms | 3.1 | 3.3 | 3.1 |
| Hands | 1.7 | 2.0 | 2.1 |
| Legs | 3.2 | 3.8 | 4.3 |
| Feet | 3.4 | 3.9 | 4.1 |
| Total | 3.3 | 3.6 | 3.8 |

a 12 volt supply
b 24 volt supply
c 1.2 clo without the cap

The effect of applying 12 volts to the bag heating element increased the total bag insulation by only approximately 10%; with 24 volts the increase was only 15%. This low percentage increase in effective insulation occurred because the thermostat which controlled the electrical current to the heater kept reaching its set-point temperature and turning the heater current off.

This sleeping bag, unheated, would allow heat balance at an air temperature of 14°C (57.2°F) assuming a heat production of 0.8 Met or 46.5 watts/$m^2$ (40 kcal/hr/$m^2$), with 25% lost by evaporation and a minimum mean skin temperature for comfort of 32°C (89.6°F). Burton's equation for the efficiency of auxiliary heating within an insulating material gave an efficiency rating of 50% for the bag heater. Using this efficiency value, and assuming continuous heating of the bag heater, the air temperature at which heat balance should be able to be maintained would be 7°C (44.6°F). Similarly, if 24 volts DC were applied to the bag heater, the air temperature at which heat balance should be maintainable becomes -7°C (19.4°F).

This item clearly does not show promise for Army use. However, it is essential to distinguish between failure of an unsatisfactory marriage between the application of electric heat and a specific sleeping bag, and the still undemonstrated, but probable, benefit of using electric heating in an extreme cold weather sleeping bag or casualty evacuation bag. The following suggestions are made, based upon the above results, and seem appropriate to consider for improving this, or a similar item:

1. Provide increased insulation by adding between 1 and 1-1/2 lb of a better quality polyester filling material.
2. Provide a zipper or velcro closure for the bag opening.
3. Provide a built-in face and head protective hood or mask to stop a chimney ventilating effect.
4. Increase width and length dimensions, since these were inadequate to really accommodate the medium size copper man.
5. Increase the insulation at the bag foot end.

The built-in pillow located at the bottom of the stuff sack seems an excellent feature; it should add a measure of comfort as well as warmth. Finally, this unsatisfactory application of electric heat clearly indicates that electrical heating of

an inadequately insulated bag is a waste of time, a fact that has long been known. The fault does not lie with the application of electric heat to this problem, but with the lack of sleeping bag expertise of the applicator.

<u>Presentations:</u>

None

<u>Publications:</u>

None

## II. STUDIES ON UNIFORM SYSTEMS

Background:

Measurements of insulation (clo) values are sufficient to allow calculation of heat losses from the soldier in a cold environment. However, in hot environments, evaporation of sweat through clothing systems becomes a key feature of tolerance, and performance degradation estimates and measurement of the moisture permeability index ($i_m$) using the copper manikin in the "sweating" mode become most important. A variety of questions are continually asked about proposed new uniforms, commercial clothing items, foreign uniform systems and specialized, auxiliary heated, ventilated or cooled systems. These latter can be most accurately measured using a sectionalized heated copper manikin which allows independent measurement of the insulating (clo) and evaporative transfer ($i_m$) characteristics of six sections: the head, torso, arms, legs, hands and feet.

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|---|---|
| Program Element: | 6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE |
| Project: | 3E762777AB45 Environmental Stress, Physical Fitness and Medical Factors in Military Performance |
| Work Unit: | 048 Biomedical Impact of Military Clothing and Equipment Design Including the Selection of Crew Compartment Environments |
| Study Title: | Evaluation of Women's Field Clothing |
| Investigators: | Clement A. Levell, John R. Breckenridge, Ralph F. Goldman, Ph.D. |

**Background:**

A program is anticipated for development of new field clothing for women. In order to initiate this effort, it was necessary to ascertain the insulating characteristics of the clothing presently being prescribed. At present, standard WAC clothing is worn in the warm weather and then, by add-on of standard field clothing, the insulation is intended to be sufficient for Cold-Wet environments.

USARIEM was requested to consider undertaking both a copper "womanikin", as well as a chamber study of the standard women's field clothing. Since the clo values obtained in the womanikin study were substantially different from those obtained from previous studies of men's cold-wet field clothing, consideration was also given to an add-on of Men's Field Trousers to the Women's cold-wet clothing.

**Progress:**

Insulation (clo) and evaporative index ($i_m$/clo) measurements were made on eight Women's Army uniform combinations ranging from a fatigue uniform to a complete cold-wet system which included both slacks and a skirt, and a field jacket with wool liner. A winter uniform with two lengths of skirt, and also with either wool jacket or long-sleeve sweater were included to assess the effect of skirt length, and compare the protection improvements of the jacket vs the sweater. Results indicated that the complete cold-wet uniform provided almost 1 clo less

insulation than the men's cold-wet uniform, primarily because the men's uniform has an additional layer over the legs in the form of field trousers with liner instead of wool slacks (women's). Skirt length in the winter uniform (knee length vs calf length) had only minor effect on insulation, but the evaporative index ($i_m$/clo) was 20% higher (0.46 vs 0.38) with the shorter skirt. Such an increase in evaporative cooling would be especially beneficial in preventing discomfort and overheating on warm days; these guidelines would apply equally well to summer skirts, especially those designed for hot-humid environments where evaporative cooling would be an essential requirement for comfort and/or operational effectiveness. Complete results and a comparison with men's clothing values are given below:

Evaluation of Women's Field Clothing

| Ensembles | Clo | $i_m$ | $i_m$/clo |
|---|---|---|---|
| A. Cold Wet | 2.0 | .33 | .16 |
| B. Cold Wet w/o wool shirt | 1.9 | .34 | .18 |
| C. Fatigues | 1.3 | .43 | .33 |
| D. Fatigues + field jacket | 1.6 | .41 | .26 |
| E. Winter (mid calf) | 1.2 | .45 | .38 |
| F. Winter (knee) | 1.0 | .48 | .46 |
| G. F + Jacket | 1.8 | .54 | .30 |
| H. F + Sweater | 1.3 | .61 | .46 |
| Men's Cold Wet | 3.0 | .28 | .09 |
| Men's Fatigues, Utility | 1.4 | .43 | .31 |
| Men's Cold-Dry | 4.7 | .32 | .07 |

Thermographic analysis of local heat losses were also performed to identify local leakage of heat through seams, underinsulated areas and the like. These values for insulation provided female soldiers are particularly interesting in view of reported male and female differences in physiological tolerance to environmental extremes (1).

**Presentations:**

None

**Publications:**

None

LITERATURE CITED

Annual Progress Report, FY 76, US Army Research Institute of Environmental Medicine, Pp. 111

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|---|---|
| Program Element: | 6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE |
| Project: | 3E762777AB45 Environmental Stress, Physical Fitness and Medical Factors in Military Performance |
| Work Unit: | 048 Biomedical Impact of Military Clothing and Equipment Design Including the Selection of Crew Compartment Environments |
| Study Title: | Reflective Liners with Foam Spacers for Improved Arctic Uniform Insulation |
| Investigators: | Clement A. Levell, Ralph F. Goldman, Ph.D. |

Background:

A new, commercially patented, approach to application of reflective layers in cold weather clothing, namely, use of reflective surfaces next to perforated, low-density foams was studied for its insulating merits in extreme cold weather protective systems.

Progress:

This approach was evaluated by incorporating the reflective systems into the standard Arctic uniform in lieu of the conventional quilted polyester liners. Copper manikin measurements showed that these reflective liners increased the Arctic uniform insulation by 10%, from 4.4 to 4.8 clo, and did not alter the permeability index (0.31). However, the increased insulating value did cause a slight reduction in $i_m$/clo (the evaporative index) from 0.07 to 0.06. The 10% insulation increase with the reflective liners was no greater than that found in studies with quilted polyester liners faced with reflectives; the perforated foam liners, moreover, increased the weight of the standard ensemble. Since insulation of these liners was provided strictly by air spaces between the reflectives, rather than by air trapped in a polyester batt, it was recommended that the comparisons of these with the standard liners be extended to include measurements in wind or with simulated body motion. Either of these reduces insulation effectiveness of a free, i.e.,

unfilled, air space and would probably eliminate even the 10% gain found with this approach.

This study has been completed, but other studies will be initiated as promising approaches/applications for reflectives are recognized.

Presentations:

None

Publications:

None

| | |
|---|---|
| Program Element: | 6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE |
| Project: | 3E762777AB45 Environmental Stress, Physical Fitness and Medical Factors in Military Performance |
| Work Unit: | 048 Biomedical Impact of Military Clothing and Equipment Design Including the Selection of Crew Compartment Environments |
| Study Title: | Evaluation of "Belson Infiltrator" Vest Versus the Lincloe Load Carriage System |
| Investigators: | Clement A. Levell and Ralph F. Goldman, Ph.D. |

Background:

A physiological evaluation, completed in February 1970, compared the "Belson Infiltrator" vest with the M-79 ammunition carriage vest and showed no significant benefit from use of the commercially developed, Belson system. DARCOM directed a comparison of the infiltrator vest with the Lincloe load carriage system and as one part of the program, we were requested by NARADCOM to compare the physiological effects of wearing these two systems; the Human Engineering Lab at Aberdeen was funded to evaluate Human Factors aspects.

Progress:

A comparison study to determine the relative heat stresses imposed by wearing the Belson Infiltrator vest and Lincloe load carriage system, respectively, was performed using the "sweating" copper manikin dressed in tropical fatigue uniform. Comparison of these two load carriage systems on the manikin indicated that both would impose approximately the same heat stress, judging from the clo and $i_m$/clo (evaporative index) values measured, despite the fact that the area coverages and number of pouches were different. The Belson vest measured 1.53 clo and 0.25 for $i_m$/clo, versus 1.48 clo and 0.26 for $i_m$/clo with the Lincloe system.

Accordingly, we advised against a physiological heat stress comparison with volunteers since there was little likelihood of showing a difference on human subjects.

Presentations:

None.

Publications:

None.

| | |
|---|---|
| Program Element: | 6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE |
| Project: | 3E762777AB45 Environmental Stress, Physical Fitness and Medical Factors in Military Performance |
| Work Unit: | 048 Biomedical Impact of Military Clothing and Equipment Design Including the Selection of Crew Compartment Environments |
| Study Title: | Evaluation of Fine Fiber Uniforms |
| Investigators: | Clement A. Levell and John R. Breckenridge |

## Background:

Experimental fine fiber materials are being investigated by NARADCOM clothing developers to assess their merits as insulating materials. Claims for improved insulation characteristics have been made by one manufacturer; in addition, their higher density and improved resistance to compression, compared with polyester battings currently used for liners of cold weather clothing, make fine fibers appear to be appropriate for use at pressure points, such as under armpits, over the elbows, seat, and knees, etc. Conventional polyester, which compresses easily, is notably deficient at these pressure points and permits unacceptable heat leakage.

## Progress:

Fine fiber materials show little promise, on an insulation per unit weight basis, in our evaluations to date. Three coveralls, one with fine fiber lining and the other two with polyester (fiberfill) linings were compared on the copper manikin. Size and weight data for the coveralls, and insulation and evaporative index ($i_m$/clo) values for the ensembles measured, which included combat boots, wool socks, and utility cap, are given in Table 1.

Table 1. Insulation (clo) and Evaporative ($i_m$/clo) Characteristics of Fine Fiber Lines.

| | Size | Wgt. | clo | $i_m$ | $i_m$/clo |
|---|---|---|---|---|---|
| Dark blue coverall, beige lining: Fine fiber lining, | 46L | 2069g | 2.44 | .43 | .18 |
| Dark blue coverall, ripstop lining: 2 oz, bonded fiberfill- (MIL B-41826D type I) | 44L | 1292g | 2.07 | .43 | .21 |
| Royal blue coverall, gray lining: 3.25 oz, bonded fiberfill | 44R | 1550g | 2.26 | .43 | .19 |

Although the fine fiber coverall was much heavier in weight than either coverall with polyester lining (60% heavier than b. and 33% heavier than c.), the insulation values with the fine fiber lining were only 18% and 8% higher than with polyester, respectively. This lack of superior insulating characteristics for fine fiber materials was also noted in a study of gloves incorporating fine fiber liners. Nevertheless, since fine fiber webs can be produced in a tremendous range of bulk densities, we anticipate that the NARADCOM developers will ask for additional studies of these fibers in the future. Future work will be contingent on interest of NARADCOM clothing developers in the fine fiber approach to providing thermal protection.

Presentations:

None.

Publications:

None.

Program Element: 6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE

Project: 3E762777AB45 Environmental Stress, Physical Fitness and Medical Factors in Military Performance

Work Unit: 048 Biomedical Impact of Military Clothing and Equipment Design Including the Selection of Crew Compartment Environments

Study Title: Post Office Cold Weather Clothing Evaluation

Investigators: Clement A. Levell and Ralph F. Goldman, Ph.D.

Background:

NARADCOM, who fund many of our studies of clothing are also the developers of clothing systems for the US Postal Service. In cold weather regions such as Southern Alaska and Northern portions of the lower US, Post Office delivery personnel are authorized the wear of a Sur-Coat over their other clothing. It must be noted that wearers do not always wear the prescribed or suggested clothing. A proposal has been received suggesting that a cold weather coverall be authorized in lieu of the Sur-Coat and Trousers. In order to ascertain the differences in insulation characteristics between the two clothing systems, it was believed necessary that a physiological evaluation based on a copper manikin study be conducted.

Progress:

The experimental Post Office ensemble incorporating work coveralls plus cold weather coveralls in lieu of a Sur-Coat and Trousers provided 0.27 clo better insulation than the standard ensemble (2.93 vs. 2.66), and did so with a weight reduction of 4.1 lbs. (16.2 lbs. vs 20.3 lbs for the standard). The evaporative cooling index ($i_m$/clo) for the experimental ensemble was slightly lower than that

for the standard uniform, but only because the insulating (clo) values were different. The experimental uniform also had three fewer items of clothing and was less bulky than the standard.

Presentations:

None.

Publications:

None.

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|---|---|
| Program Element: | 6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE |
| Project: | 3E762777AB45 Environmental Stress, Physical Fitness and Medical Factors in Military Performance |
| Work Unit: | 048 Biomedical Impact of Military Clothing and Equipment Design Including the Selection of Crew Compartment Environments |
| Study Title: | Evaluation of Summer Weight Shirting from India |
| Investigators: | Clement A. Levell and John R. Breckenridge |

Background:

A shirt of the type worn in India in hot/humid areas has been obtained. It appears highly air permeable, and is claimed to be unusually comfortable even without wind. A simple copperman evaluation of clo and $i_m$ and a measure of weight and thickness, should indicate whether there is anything unique in this item on the basis of clo/thickness, clo/weight, thickness/weight or $i_m$/clo ratios. This type of material has gained great favor in the U.S. civilian market and, if these claims are substantiated, we would recommend that the U.S. Army clothing developer to consider potential military applications.

Progress:

The clo and $i_m$/clo values of a standard fatigue uniform are being compared with values for the same uniform but with the Indian shirt substituted for the fatigue jacket. Data collection is not yet complete.

**Presentations:**

None.

**Publications:**

None.

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|---|---|
| Program Element: | 6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE |
| Project: | 3E762777AB45 Environmental Stress, Physical Fitness and Medical Factors in Military Performance |
| Work Unit: | 048 Biomedical Impact of Military Clothing and Equipment Design Including the Selection of Crew Compartment Environments |
| Study Title: | Local Insulation and Heat Leakage Sites in the Standard U.S. Army Arctic Uniform |
| Investigators: | George F. Fonseca, Clement A. Levell and Ralph F. Goldman, Ph.D. |

## Background:

The sectional copper man permits identification of the relative contributions of the insulative protection provided to six major areas of the body; head, torso, arms, legs, hands and feet. However, while it can identify those areas with less insulation than provided other parts of the body, i.e. the "weak links," use of the infrared scanning AGA camera allows us to further localize heat leaks within each section, even identifying specific seams, metal fasteners etc. as potential weak links. A combined evaluation of the Arctic uniform was requested by the US Army Natick Research and Development Command.

## Progress:

Both the determination of the local and total heat transfer properties (clo, $i_m$, and $i_m$/clo) of the standard arctic uniform measured on the sectional manikin and the AGA camera photographs showing the heat leakage sites in the standard Arctic uniform, while worn on the heated sectional manikin, have been completed.

This study was performed in a cold chamber with an air temperature of 0°F (−17.8°C). The local and total heat transfer properties are given in Table 1.

TABLE 1

HEAT TRANSFER PROPERTIES OF STANDARD ARCTIC UNIFORM

| Manikin Sections | clo | $i_m$ | $i_m$/clo |
|---|---|---|---|
| Torso | 7.0 | 0.56 | 0.08 |
| Arms | 4.8 | 0.43 | 0.09 |
| Legs | 4.5 | 0.50 | 0.11 |
| Head | 2.8 | 0.31 | 0.11 |
| Hands | 3.3 | 0.36 | 0.11 |
| Feet | 2.7 | 0.22 | 0.08 |
| Total | 4.4 | 0.44 | 0.10 |

As anticipated from the laws of physics, the greatest insulation is provided over the torso and the least over the head, hands and feet. The insulation over the torso and feet show the lowest evaporative heat transfer values (i.e. $i_m$/clo). Since the torso area approximates 28% of the total body surface, the importance of opening or removing some of these torso garments is apparent. Otherwise, moisture taken up by the clothing continues to evaporate after activity ceases, resulting in what is termed after-exercise chill, i.e., cooling in excess of heat production.

Twenty-nine AGA camera slides were taken showing the various heat leakage sites over the clothing surface. These sites were located at the shoulders (caused by compression of the insulation over the shoulders), at the waist/crotch area (caused by compression of the insulation by the parka drawstring), at the lower arm and hand areas (due to compression of insulation by the mitten drawstrings), at the ankles (caused by the thin wall insulation at the ankle lacings) and at the face opening of the hood. Additional AGA camera work will be continued to analyze heat leakage in clothing, sleeping, and handwear systems.

Presentations:

None.

Publications:

None.

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|---|---|
| Program Element: | 6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE |
| Project: | 3E762777AB45 Environmental Stress, Physical Fitness and Medical Factors in Military Performance |
| Work Unit: | 048 Biomedical Impact of Military Clothing and Equipment Design Including the Selection of Crew Compartment Environments |
| Study Title: | (1) Evaluation of Air Force Anti-Immersion Protective Clothing Systems and (2) Evaluation of One Naval Aviator Anti-Immersion Ventile Suit |
| Investigators: | James Bogart, Thomas Endrusick, Ralph F. Goldman, Ph.D. and Louis Strong, Ph.D. |

## Background:

In accordance with an Agreement of Understanding between the US Air Force and US Army Research Institute of Environmental Medicine under which we were furnished their non-functioning copper manikins for our retention and use, insulation measurements were determined on ventile anti-immersion protective clothing systems using our waterproofed copper manikin.

## Progress:

Twenty-three separate determinations were made, involving measurements of the suits in air, in water and two measurements with the manikin in a life raft. One Navy ventile suit was included at the request of the Air Force. The suit components and insulation values are given in Table 1.

TABLE 1. Calculated Insulation Values

| # | ENSEMBLE | AVE. SKIN TEMP (°C) | AVE. AMBIENT TEMP (°C) | INSULATION (CLO) |
|---|---|---|---|---|
| | **MEASUREMENTS IN AIR** | | | |
| 1. | Nude | 32.6 | 25.7 | 0.86 |
| 2. | Navy Suit | 32.5 | 24.5 | 2.43 |
| 3. | USAF Basic Ensemble[a] | 32.7 | 26.1 | 2.34 |
| 4. | Basic + Space Garment | 32 | 25.7 | 2.48 |
| 5. | Basic + Fishnet UW | 32. | 24.7 | 2.63 |
| 6. | Basic + Anti-G Suit | 32.7 | 25.6 | 2.56 |
| 7. | Basic + 9/p UW + Anti-G | 32.7 | 25.9 | 3.14 |
| 8. | Basic + 9/p UW + Fishnet UW | 32.7 | 25.3 | 3.14 |
| 9. | Basic + Batted UW | 32.7 | 25.4 | 2.98 |
| 10. | Basic + Extra Nomex Top + Anti-G | 32.7 | 25.5 | 2.72 |
| 11. | USAF Summer Ensemble CB[b] | 32.6 | 25.6 | 2.66 |
| 12. | Basic + 9/p UW | 32.6 | 24.6 | 3.34 |
| 13. | Basic on Raft | 32.6 | 24.2 | 3.45 |
| 14. | USAF (2) Sets Nomex, Flight Suit + Anti-G | 32.5 | 23.2 | 2.31 |
| 15. | Basic on Raft (on 23°C water) | 32.4 | 23.1 | 3.02 |
| 16. | Basic on Raft (on 17°C water) | 32.2 | 20.2 | 3.09 |
| | **MEASUREMENTS IN 22°C WATER** | | | |
| 17. | Nude | 26.0 | 21.6 | 0.18 |
| 18. | Navy Suit | 29.3 | 21.8 | 0.46 |
| 19. | USAF Basic | 27.0 | 21.8 | 0.30 |
| 20. | Basic + 9/p UW | 27.8 | 21.9 | 0.35 |
| 21. | USAF Anti-Exposure Ensemble CB[c] | 26.7 | 21.6 | 0.32 |
| 22. | Basic + Extra Nomex Top + Anti-G | 27.5 | 21.6 | 0.32 |
| 23. | USAF (2) Sets Nomex + Flight Suit + Anti-G | 26.9 | 21.0 | 0.30 |

a. USAF Basic Ensemble

(1) APH-5 helmet, in air and water
(2) Inflatable anti-exposure flyers mittens (Hau-12/p)
(3) Leather (combat) boots
(4) Heavy wool socks
(5) Anti-exposure (Nomex) flyers undershirt (CWU-44/p)
(6) Anti-exposure (Nomex) flyers drawers (CWU-43/p)
(7) Nomex flight suit (CWU-27/p)
(8) Anti-exposure (Ventile) suit (CWU-21/p)

b. Nomex UW & Charcoal Garment + Flight Suit + CB Hood + APH-5 Helmet

c. Same as 1, with Ventile Garment

The implications of these results in terms of heat loss were supplied the Air Force, using the presentation shown in Table 2.

TABLE 2. Relative Heat Loss of Ensembles Measured

| Clo Range | Suits Represented (numbered as in Table 1) | Heat Loss (In $5^{o}$C Air) Watts | kcals/hr |
|---|---|---|---|
| | | 2.0 clo = 165 | 142 |
| 2.00 to 2.50 | 2,3,4,14 | 2.5 = 165 | 114 |
| 2.50 to 3.00 | 5,6,9,10,11* | 3.0 = 110 | 95 |
| 3.00 to 3.50 | 7,8,12,13*,15,16 | 3.5 = 94 | 81 |

*Raft in air
Raft in water

| Clo Value | | (In $5^{o}$C Water) | |
|---|---|---|---|
| 0.18 | 17 | 1838 | 1581 |
| 0.30 | 19,23 | 1103 | 948 |
| 0.32 | 21,22 | 1034 | 889 |
| 0.35 | 20 | 945 | 813 |
| 0.46 | 18 | 719 | 618 |

For a man in a resting state, heat loss from the lungs = 12.5% of metabolic heat production or ~ 15 kcal/hr with a total heat production of ~120 kcal/hr. Each loss of ~ 60 kcal (i.e., a heat debt of 60 kcal difference between heat production and heat loss) corresponds to a fall of $1^{o}$C in body temperature. A fall of 3-$5^{o}$C in body temperature is serious and a fall of 5-$10^{o}$C can be fatal.

Since the suits supplied had faulty seals which allowed water to enter and the ventile material appeared to leak readily, the measured insulation values in water were reduced below "dry" suit values to an undetermined extent. Plans to repeat the measurements after the USAF had corrected the leakage problem were abandoned for lack of success in improving the ventile materials.

**Future Plans:**

None, until sealing and leakage problems are solved.

**Presentations:**

None.

**Publications:**

None.

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|---|---|
| Program Element: | 6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE |
| Project: | 3E762777AB45 Environmental Stress, Physical Fitness and Medical Factors in Military Performance |
| Work Unit: | 048 Biomedical Impact of Military Clothing and Equipment Design Including the Selection of Crew Compartment Environments |
| Study Title: | Evaluation of "Dry" Type Navy Diver Suits |
| Investigators: | James Bogart, Thomas Endrusick, Louis Strong, Ph.D., Ralph F. Goldman, Ph.D. and John R. Breckenridge |

Background:

One of our copper manikins was converted for water immersion studies some ten years ago, and was used extensively in collaborative studies to support the US Navy Man in the Sea Program. Use of this device has, subsequently, been limited to studies for developing the heat transfer characteristics of humans exposed with and without protective clothing to water of various temperatures. These studies have been oriented toward 1) developing a better understanding of human whole body cooling and 2) developing a prediction model of human hypothermia. The US Naval Coastal Systems Laboratory (NCSL) requested that we carry out evaluations of a variety of anti-immersion "dry" suits for them, under an interagency fund transfer. The NCSL was interested in our evaluating various commercial anti-immersion "dry" suits, to provide data for selection and standardization of protective suits by the Navy. US Army Research Institute of Environmental Medicine (USARIEM) interest in such studies stems from related questions on protection for Army aircrew flights over water, for Army "Seal" teams, and for Riverine and swamp crossing operations.

Progress:

Insulation measurements on the "dry" suits alone and in combination with

various undergarments were made in air and with the copper manikin immersed to the neck. Representative results in 14°C water are given in Table 1.

TABLE 1. Thermal insulation provided by "dry" anti-immersion suits, in water.

| Suit Description | Insulation Values (clo) | |
|---|---|---|
| | Suit Alone[a] | Range with Undergarments[b] |
| Unisuit | 0.91 | 1.13 - 1.55 |
| Viking | 0.35 | 0.73 - 0.87 |
| O'Neill Supersuit | 0.85 | 0.96 - 1.27 |
| White Stag | 0.96 | 1.11 |
| Imperial | 0.94 | --------- |
| Sub Aquatic Systems | 0.77 | --------- |

a. Suits in deflated state.

b. Undergarments included various commercial foam, fabric, and spacer type items.

Evaluation of selected systems (from those already tested) is scheduled for the coming fiscal year, under water pressures of up to 32 ATA, using the NSCL facility at Panama City, Florida.

Presentations:

None.

Publications:

None.

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| Program Element: | 6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE |
| Project: | 3E762777AB45 Environmental Stress, Physical Fitness and Medical Factors in Military Performance |
| Work Unit: | 048 Biomedical Impact of Military Clothing and Equipment Design Including the Selection of Crew Compartment Environments |
| Study Title: | CW Agent Protective Patient Wrap (UK) for Casualty Evacuation. |
| Investigators: | Clement A. Levell, Ralph F. Goldman, Ph.D. and John R. Breckenridge |

## Background:

In connection with the development of a patient wrap for protection of wounded men in a chemical warfare (CW) environment, heat stress characteristics of United Kingdom (UK) CW Patient Wrap were evaluated.

## Progress:

Heat transfer characteristics were determined with a "sweating" copper manikin dressed similarly, i.e. combat tropical fatigues, as in our study of an earlier UK CW Patient Wrap. Results of the two studies, with wraps on standard inflatable mattresses are shown in Table 1.

TABLE 1.
Clo and $i_m$/Clo Values forTwo UK CW Patient Wraps

| | clo[a] | $i_m$ | $i_m$/clo |
|---|---|---|---|
| 1974 Wrap | 2.27 | .28 | .12 |
| 1977 Wrap | 2.24 | .22 | .10 |

[a]Calculated using weighted environmental temperature of 75% ambient temperature plus 25% of temperature between bag and pad (our standard weighting in sleeping bag studies)

The 1977 patient wrap shows greater resistance to evaporative transfer than the US T-70-1 chemical protective suit worn with hood, gloves, and mask (clo = 2.07, $i_m$/clo = 0.18). This greater resistance is due to use of an impermeable layer on the underside of the wrap to prevent wetting through at pressure points. The decreased evaporative potential, compared to the 1974 version, which had no impermeable layer, is not considered a serious problem for an inactive patient, who would presumably not be kept in the wrap for extended periods. However, if the patient were also wearing CW clothing in the wrap, monitoring his heat build up during extended transport to an aid station at temperatures above 25°C would be an appropriate precaution.

Presentations:

None.

Publications:

None.

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|---|---|
| Program Element: | 6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE |
| Project: | 3E762777AB45 Environmental Stress, Physical Fitness and Medical Factors in Military Performance |
| Work Unit: | 048 Biomedical Impact of Military Clothing and Equipment Design Including the Selection of Crew Compartment Environments |
| Study Title: | Evaluation of Aviators Nomex Uniforms with US and UK Chemical Protective Clothing Systems. |
| Investigators: | Clement A. Levell and Ralph F. Goldman, Ph.D. |

Background:

The UK utilizes a CW protective undergarment for wear under their aircrew and tankers' clothing which is thinner and lighter in weight than the US standard clothing Outfit, Chemical Protective. Thus, from a physiological viewpoint, the foreign item may be more beneficial to individuals. In view of the substantial heat stress associated with these multiple layer, reduced permeability systems, we have been requested to investigate this aspect.

Progress:

A standard Aviator's Nomex 2 pc uniform was evaluated in combination with three chemical protective garments; two were US and one was a UK item. All systems included the US mask and hood, aviator's helmet, combat boots and chemical protective gloves. Results are given in Table 1.

Table 1. Clo and $i_m$/clo Evaluations of Aviator's CW Systems

| | clo | $i_m$ | $i_m$/clo |
|---|---|---|---|
| Nomex uniform plus | | | |
| US charcoal overgarment | 2.59 | .29 | .11 |
| US impregnated liner | 2.01 | .29 | .14 |
| UK charcoal undergarment | 2.08 | .32 | .15 |

The US impregnated liner and UK undergarment provide approximately the same resistance (clo) to dry heat transfer, but the combination with UK undergarment is slightly better for evaporative cooling ($i_m$/clo). The US overgarment system provides higher insulation (and lower $i_m$/clo) because it is thicker and bulkier. Based on their data, it was concluded that, since pilots would be sedentary and not producing more than 125 kcal/hr of metabolic heat, none of the systems would cause extreme heat stress under flight conditions.

Presentations:

None.

Publications:

None.

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| Program Element: | 6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE |
| Project: | 3E762777AB45 Environmental Stress, Physical Fitness and Medical Factors in Military Performance |
| Work Unit: | 048 Biomedical Impact of Military Clothing and Equipment Design Including the Selection of Crew Compartment Environments |
| Study Title: | Evaluation of West German Chemical Protective System |
| Investigator: | Clement A. Levell and Ralph F. Goldman, Ph.D. |

## Background:

A West German charcoal impregnated chemical protective overgarment was evaluated for thermal stress characteristics (clo and $i_m$) on the "sweating" copper manikin to determine its environmental protection merits relative to those of comparable US, UK and Canadian items. Visual inspection of this item suggested that a different method of applying the charcoal absorbent had been employed; this difference could affect the water vapor transfer characteristics of the West German overgarment. The overgarment was evaluated over two West German uniforms; one appeared to be a warm climate uniform and the other a uniform designed for wear in somewhat cooler environments, perhaps in ambient temperatures from 5 to 15°C. These two basic uniforms were also measured. In addition, the West German overgarment was measured over standard U. S. fatigues to provide a suitable basis for comparison with US, UK and Canadian items, which have been measured over fatigues. Chemical protective modes were studied two ways, "open" and "closed"; i.e. with and without gas mask, hood and gloves.

## Progress:

Measurements to assess the heat stress characteristics of the West German overgarment have been initiated. Data collection on the "sweating" copper manikin is currently in progress.

Presentations:

None.

Publications:

None.

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|---|---|
| Program Element: | 6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE |
| Project: | 3E762777AB45 Environmental Stress, Physical Fitness and Medical Factors in Military Performance |
| Work Unit: | 048 Biomedical Impact of Military Clothing and Equipment Design Including the Selection of Crew Compartment Environments |
| Study Title: | Water Retention by Kevlar Body Armor and Heat Transfer Characteristics and Moisture Uptake of Kevlar Undershirt Style Body Armor |
| Investigators: | John R. Breckenridge, Clement A. Levell and Thomas Endrusick |

## Background:

A new California law mandates that state police be provided with Kevlar Body Armor and no manufacturer will be authorized to sell the armor unless certified by a special State Division. The time frame for such purchase has been specified but no manufacturers are certified and they need specifications. This particular program is a direct result the Army work (in which we cooperated) to develop a Kevlar vest. The Army vest, of 1500 denier, 14 ounces/yd$^2$ Kevlar, water repellent treated material, made up into 13 plies, was unique at the time. Subsequently, under impetus of the Law Enforcement Assistance Agency (LEAA), a large Kevlar armor program was developed (in which we again participated). A Protective Body Armor Manufacturers Association has been found and under a \$1,000,000 Aerospace Corporation contract, experience with some six to eight thousand vests in 15 cities across the country is being gathered; to date, 15 officer's lives have been saved by these vests in documented situations.

Unfortunately for the soldier, Type Classification of the Kevlar vest is not anticipated until November 1978, although it may be foreshortened because of 100% troop acceptance in tests to date. Nevertheless, the vest that is to be Type Classified is now already obsolete in terms of new Kevlar, new treatments, etc., that have been developed by this burgeoning industry. The Army MP's want such armor, approximately 12,000 are needed by the Air Force for security officers

(SAC bases); these groups are proposing to buy the commercial vests, in part because the Army item is obsolete, because, as yet, there is no Basis of Issue for it and, also because the commercial vests is less conspicuous. The MP's have their own Test Division to evaluate such items and, since they cannot buy the Army item, commercial purchases may be made that may, or may not, be as good as the already obsolete Army vest.

One problem with Kevlar has been that when wet, it apparently loses a great deal of its penetration resistance. All Army work was on water repellent treated Kevlar. In industry, different deniers and weights of material are being used, some are water repellent treated, others use an elastomeric coating of the fabric, while still others simply encase in a vinyl bag. The elastromeric coating provides partial water resistance and helps stiffen the armor, since the fibers are immobilized and there is less elongation on impact. However, it is appreciably less expensive to simply in case the plies of armor in a vinyl envelope, so this is frequently done despite the fact that the vinyl envelope produces total impermeability in our experience, the water repellent treated Kevlar was 3/4 more permeable than an armor vest in a vinyl envelope which covered an approximate similar area. Data on the water repellent treated Kevlar vest also indicated that some 250 grams of water were accumulated in the vest worn on a sweating copper manikin for 4 to 6 hours. This situation, where liquid water is not dripped onto the vest as rain or into the vest as sweat droplets suggests that water accumulation during actual use may be substantially greater.

A specific issue is test methods whereby resistance to penetration of wet Kevlar armor can be determined, e.g. clay backing of armor, temperature, degree of packing, etc. However, a critical prediction is how wet testing should be performed. A proposed specification is a one to two hour soak in water at $25 \pm 5^{o}C$ and then, within one hour after removal, test the vest for ballistic resistance with 9 mm, 38 and 22 caliber bullets. The realism of this procedure is open to question, i.e., water uptake following soaking may not compare with that absorbed during copper man or human testing. It has also been suggested that the vest be agitated during the soaking procedure to cause maximal penetration of water between the fibers.

It seems in the Army's interest to work on this and, accordingly, limited evaluation will be done of the wetting and water retention of Kevlar vest material in comparison with that absorbed from the copper man. An additional two days of sweating copper man runs will be carried out on the new commercial 8-1/2 oz/sq yd, not repellent treated, 1000 denier, 16 ply Kevlar armor currently in favor by industry.

Progress:

Two studies, in collaboration with US Army Natick Research and Development Command developers, on 7 and 16 ply Kevlar ballistic undershirt vests have been conducted to: 1) determine the increased heat stress associated with wearing such a vest; 2) establish design requirements for minimizing sweat uptake during wear and 3) develop procedures for wetting the vests which would provide realistic "after wear" water uptake prior to measuring ballistic effectiveness, i.e., result in water uptake similar to that produced after several hours wear by an active individual.

Initial manikin studies on a 16 ply cotton carrier, indicated that evaporative cooling was almost completely blocked by this vest. The evaporative cooling index ($i_m$/clo) for the complete police ensemble (including reefer coat) with vest was 0.11, 21% less than the 0.14 value obtained earlier with a 7 ply vest. The 16 ply vest covered only 26% of the body area but the $i_m$/clo index with this heavy uniform was only slightly (0.02) higher than for an impermeable totally encapsulating ensemble (such as CW clothing). It was concluded that use of a waterproof vinyl carrier over the Kevlar, proposed by some California manufacturers to solve the water uptake problem, would probably not in this case greatly increase heat stress, although the vinyl might be less comfortable than a cotton carrier which would blot excess sweat from the skin.

Investigations to develop a suitable, non-physiological method for duplicating sweat uptake in the Kevlar prior to ballistic firings led to a recommendation of water immersion with mild agitation and flexing, of the inserts for one hour followed by drainage until dripping stopped. Four immersions of the 16 ply water

repellent inserts, the first without agitation or flexing, produced results shown in Table 1.

TABLE 1.

Water Retained in Kevlar Inserts After Immersion and Draining

| Immersion # | End of Dripping[a] (minutes) | Water Retained (Kg) | % Dry Weight |
|---|---|---|---|
| 1 (no agitation) | 25 | .20 | 13.0 |
| 2 (heavy agitation and flexing) | 40 | .35 | 22.4 |
| 3 (repeat of #2) | 40 | .44 | 28.6 |
| 4 (repeat of #2) | 40 | .47 | 30.4 |

a. After time zero - at which time 1.0 Kg water remained in inserts. In run 1, time zero occurred 10 seconds after start of drainage; in subsequent runs, time zero occurred later due to greater amounts of water retained immediately after immersion.

In each case, the water retained was greater than that after 6 hours on a heated manikin with wet cotton "skin", which raises doubts regarding acceptability of the immersion procedure. However, later field evaluations in which moderately active FBI agents wore 7 ply vests for 6 hours caused water uptakes of 13% and 27%, for non-water repellent and water repellent Kevlar plies, respectively. The 13% figure agrees with the water retained after Immersion 1, and the 27% figure with the water retained after Immersion 3. Presumably the heavy agitation, folding and flexing during Immersions 2 and 3 destroyed the effectiveness of the water repellent treatment. After wear by the FBI agents, the vest with 13% water passed ballistic tests, but the untreated vest with 27% water failed all 10 firings (.22 cal bullet penetrated all 7 plies).

Subsequent to these studies, four additional 7 ply Kevlar vests and an older military prototype, not water repellent treated, were measured on the manikin. Descriptions and results with these vests, plus the evaporative cooling index with no vest are given in Table 2.

TABLE 2.

Manikin Results for 7 ply Kevlar Vests (worn under Summer Weight Police Uniform)

| Vest[a] | clo | $i_m$/clo | 6-hour water uptake (Kg) | %Dry Weight |
|---|---|---|---|---|
| A-1 | 1.46 | .26 | .070 | 7.3 |
| A-2 | 1.52 | .30 | .129 | 11.9 |
| A-3 | 1.54 | .29 | .125 | 11.7 |
| A-4 | 1.48 | .30 | .256 | 26.2 |
| Mil. Prototype | 1.48 | .30 | .279 | 33.0 |
| No vest | 1.32 | .36 | ---- | ---- |

a. Only vests A-1 and A-2 were of water repellent treated Kevlar. Vests A-2 and A-3 consisted of Kevlar inserts in cotton carriers; vests A-1 and A-4 were integral (one-piece) vests with cotton outer shell (like Mil. Prototype).

The evaporative coefficients ($i_m$/clo) were much higher than with the 16 ply vest, primarily because a much lighter uniform was studied. However, they were 16% less than with no vest which, considering that the vests covered only 26% of the body, indicated that these vests greatly reduced evaporative cooling from the torso. Further studies of the local heat stress effects of Kevlar armor, using a sectionalized manikin, have been recommended.

Presentations:

None.

Publications:

None.

| | |
|---|---|
| Program Element: | 6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE |
| Project: | 3E762777AB45 Environmental Stress, Physical Fitness and Medical Factors in Military Performance |
| Work Unit: | 048 Biomedical Impact of Military Clothing and Equipment Design Including the Selection of Crew Compartment Environments |
| Study Title: | Thermal Evaluation of New, Air-Supplied DeMil Suit |
| Investigators: | George F. Fonseca, M.S. and Ralph F. Goldman, Ph.D. |

Background:

Chemical munitions decontamination requires complete encapsulation of the worker. The old M-3 (TAP) rubber suit with integral mask, boots and gloves presents a major problem for work in the heat. The new EOD suit, which is ventilated with filtered ambient air is unacceptable under OSHA regulations. Therefore, a new, air-supplied DeMil suit consisting of a disposable, "Tuftane" urethane plastic suit worn as the outer garment and supplied with air from an external source at 75-90 psi into an air distribution "spider", with a replaceable charcoal filter, has been developed. US Army Research Institute of Environmental Medicine (USARIEM) supported this program by conducting a heated, sectional manikin study to compare the heat burden with this system with the M-3 (TAP) garment and to estimate the impact of environmental conditions upon performance of a mission.

Progress:

A heated, sectional copper manikin was sealed in a disposable, plastic suit and both sectional and total insulation (clo), permeability ($i_m$) and effective cooling ($i_m$/clo) determinations were made with (21°C) (70°F) ventilating air delivered at 75-90 psi into the air distribution "spider" with its replaceable charcoal filter. The

sectional manikin was dressed in a fatigue uniform plus the DeMil Suit's 18 lb. backpack. Table 1 gives the sectional and total clo, $i_m$ and $i_m$/clo values for the (21°C) air delivered into the DeMil Suit at 82 psi, in a chamber environment of (21°C) and 50% relative humidity; i.e. for this phase of the study, the temperature of the air entering the DeMil Suit through the air distribution "spider" was equal to the chamber air temperature.

Data in Table 1 show that the new air-supplied DeMil Suit has approximately 20% less insulation (clo) than the M-3 (TAP) suit and provides about 6 times the potential for evaporative heat transfer at an environmental air temperature of 21°C. Further, it is estimated that at 48.9°C (120°F), the time to 50% heat casualties for unacclimatized men walking at 3 mph (1.34 m/s) is about 30 minutes in the TAP suit versus about 90 minutes for men wearing the new air-ventilated DeMil suit, based on the heat transfer data in Table 2.

TABLE 1

*Comparison of insulation (clo) and evaporative cooling ($i_m$/clo) characteristics.*

| | NEW AIR SUPPLIED DEMIL SUIT[a] (21°C air delivered to DeMil Suit at 82 psi) | | | M-3 (TAP) SUIT[b] (No Air Flow) | | |
|---|---|---|---|---|---|---|
| MANIKIN SECTIONS | clo | $i_m$ | $i_m$/clo | clo | $i_m$ | $i_m$/clo |
| TORSO | 1.9 | 0.34 | 0.18 | 2.2 | 0.04 | 0.02 |
| ARMS | 1.2 | 0.24 | 0.20 | 1.5 | 0.05 | 0.03 |
| LEGS | 1.7 | 0.24 | 0.14 | 1.4 | 0.08 | 0.06 |
| HEAD | 0.8 | 0.22 | 0.27 | 1.6 | 0.05 | 0.03 |
| HANDS | 0.9 | 0.36 | 0.40 | 1.6 | 0.03 | 0.02 |
| FEET | 1.3 | 0.05 | 0.04 | 1.9 | 0.04 | 0.02 |
| TOTAL | 1.4 | 0.25 | 0.18 | 1.7 | 0.05 | 0.03 |

a. The sectional manikin was dressed in a fatigue uniform plus the DeMil Suit and its 18 lb. backpack.

b. The sectional manikin was dressed in a suit, rubber, protective, one piece impermeable, M-3; hood, protective impermeable, M-3: mask, protective, field, M-17; gloves, toxicological agents, protective; a pair of wool socks; a pair of black boots; and covers, boot, protective, impermeable, M-1.

TABLE 2

TOTAL HEAT TRANSFER IN WATTS (non-evaporative plus evaporative heat transfer)

| ENSEMBLE | CHAMBER AIR TEMPERATURE, RELATIVE HUMIDITY | | |
|---|---|---|---|
| | (4.4°C, 40°F), 50% | (21°C, 70°F), 50% | (48.9°C, 120°F), 20% |
| New DeMil Suit[a] | 381 | 274 | 99 |
| M-3 (TAP) Suit | 239 | 122 | -74[b] |

a. 21°C air delivered to DeMil Suit at 82 psi

b. At 48.9°C there is a net heat gain from the chamber environment

Future Plans:

None. Work on this item complete.

Presentations:

None.

Publications:

None.

| | |
|---|---|
| Program Element: | 6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE |
| Project: | 3E762777AB45 Environmental Stress, Physical Fitness and Medical Factors in Military Performance |
| Work Unit: | 048 Biomedical Impact of Military Clothing and Equipment Design Including the Selection of Crew Compartment Environments |
| Study Title: | Evaluation of Liquid Cooling and Heating Garments |
| Investigators: | George F. Fonseca and Ralph F. Goldman, Ph.D. |

Background:

Increased awareness of the performance degradation experienced by air and combat vehicle crewmen during operations in tropic and desert environments, coupled with the inevitable decision that future AFV will require some form of collective protection against chemical agents, suggested that auxiliary cooling systems would be essential in the future. Accordingly, approximately five years ago, a continuing series of studies of the various options for auxiliary cooling and heating garments were initiated.

Progress:

The cooling provided by four different water-cooled undergarments was measured directly on a heated copper manikin dressed in a basic hot-weather flight ensemble. This cooling, which represents absorption of the heat produced by the metabolic processes of the body plus that from the ambient environment in the cabin, was found to be almost directly proportional to the difference between the manikin skin temperature and the temperature of the cooling water at the inlet to a water-cooled undergarment. Figure 1 illustrates the heat removed from sections

of the manikin covered by one of the water-cooled undergarments as: a) a function of the difference between the manikin surface temperature and the cooling water inlet temperature; b) and c) a function of the cooling water flow rate (l/min).

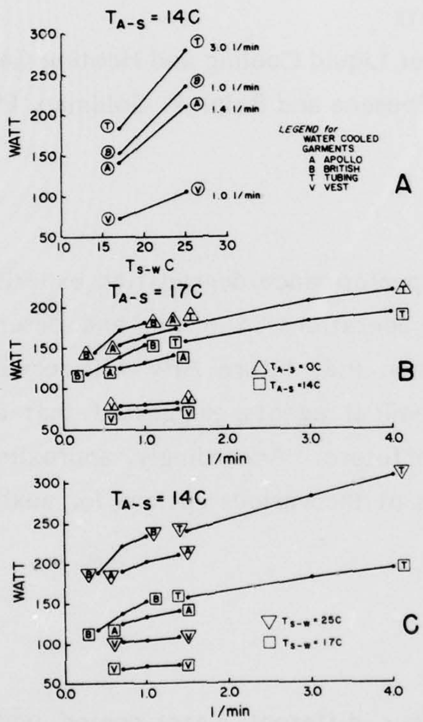


Figure 1. Heat removal by the water cooled undergarment

Although these cooling garments did not, by themselves, completely isolate the manikin surface against heat gain from the hot environment, they did remove about one-half of the potential for heat gain from the ambient environment before the

heat reached the manikin surface. Figure 2 shows the reduction in cooling (electrical watts) as a function of air temperature for these four water-cooled undergarments.

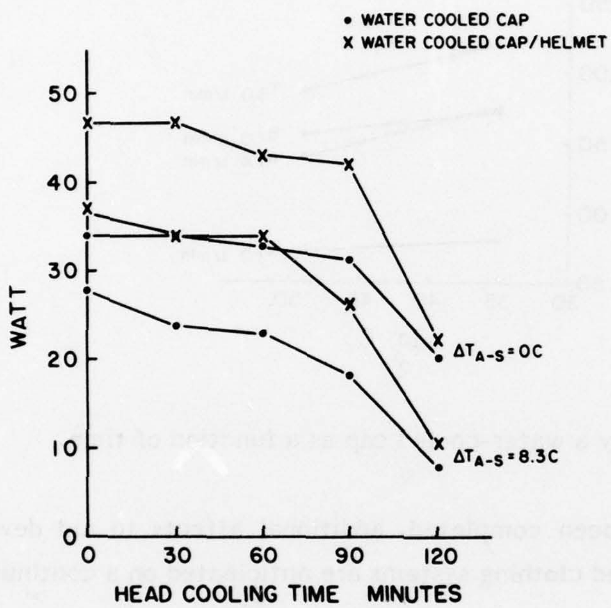


Figure 2. Interaction between cooling provided the wearer of a cooling garment and the ambient air temperature.

A water-cooled cap removed heat from the head of the manikin equivalent to about one-third of the total metabolic heat production of a seated person. The electrical watts supplied to the head of the manikin versus head cooling time in minutes when the head is covered with this water-cooled cap only and when the head is covered with this water cooled cap plus an aircrew flying helmet is given in Figure 3.

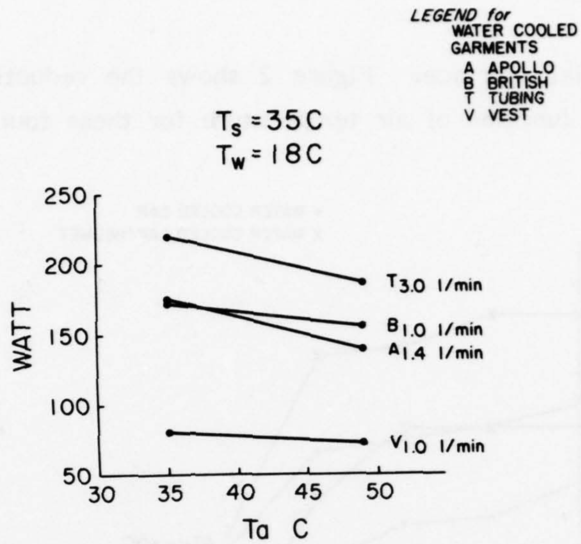


Figure 3. Heat removal by a water-cooled cap as a function of time.

Although this has been completed, additional affects to aid developers of auxiliary heated and cooled clothing systems are anticipated on a continuing basis.

Presentations:

None.

Publications:

Fonseca, G. F. Effectiveness of four water-cooled undergarments and water-cooled cap in reducing heat stress. Aviat. Space Environ. Med. 47:1159-1164, 1976.

## III HANDWEAR STUDIES

### Background:

The current goal for cold weather clothing systems, as stated in the Required Military Characteristics, is 8 hours tolerance while inactive at -40°F when there is a 3 mph wind. This requirement has yet to be met. One of the most frustrating aspects of providing this level of protection is that it is easily done for all but 5 or 10% of the total body. The clothed active soldier in the Arctic has a surplus of body heat which is distributed to the hands and feet by way of the circulating blood. Unfortunately, the circulation to the hands and feet of the inactive soldier drops as he becomes cold, from about 100cc/min to less than 1cc/min, thus eliminating almost all circulatory heat input to the fingers and toes. Thus, the hands and feet, representing only a very small part of the body, are the limiting factors in tolerance to the cold. Goldman (1) has predicted that the tolerance time for an inactive soldier, i.e., the time to cool to a finger temperature of 40°F, is only about 1½ hours at -20°F with an Arctic mitten made from the best available materials; this prediction is substantiated by actual experience with volunteer subjects in cold chamber studies.

Part of the problem of prolonging hand tolerance time in the cold, stems from the well recognized geometrical relationships for small cylinders like the fingers, i.e., a small increase in the thickness of insulation covering the cylinder greatly increases the area for heat loss. Each successive increment of added thickness provides less and less increase in insulating value, and the maximum protection that can be provided with practical handwear is of the order of 2 clo, compared with an easily attained 6 clo for clothing over the torso or with a sleeping bag. Inability to provide better protection to the fingers, and to the thumb if protected separately, prevents any great extension of tolerance time.

In view of the severe limitation in finger protection, any improvement can be an important advance. To detect the effects of design changes, a device for measuring local insulation values for each finger segment, as well as for the palm

and back of the hand, i.e., a multiple-section hand, was required. Such a device, with 23 separately heated and temperature controlled surface plates, has been available for biophysical evaluations of sectional clo values for over 10 years. It has been extensively employed to aid US Army Natick Research and Development Command designers in selecting optimal insulating materials for protective handwear, and to assess the merits of new construction techniques, effects of wear etc. "Weak links" in the overall pattern of protection for a particular handwear item can also be easily detected and remedial action taken.

Presentations:

None.

Publications:

None.

## LITERATURE CITED

1. Goldman, R. F. The Arctic Soldier: Possible research solutions for his protection. Proceedings of Fifteenth Alaskan Science Conference, College, Alaska, 1964.

| | |
|---|---|
| Program Element: | 6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE |
| Project: | 3E762777AB45 Environmental Stress, Physical Fitness and Medical Factors in Military Performance |
| Work Unit: | 048 Biomedical Impact of Military Clothing and Equipment Design Including the Selection of Crew Compartment Environments |
| Study Title: | Assessment of Worn Arctic Handwear Items |
| Investigators: | Clement A. Levell, Leander A. Stroschein, Thomas Endrusick and John R. Breckenridge |

## Background:

Two years ago, a quantity of experimental Arctic mittens incorporating polyester liners were sent to Alaska military units for evaluation and wear in the field. During Winter 1976, a few pairs of fine-fiber batting liners were also sent to Alaska for evaluation. All of these items, which were measured prior to use on the sectional copper hand, have now been returned after undergoing considerable wear. US Army Natick Research and Development Command requested that these items be remeasured and studied for signs of insulation breakdown, using the AGA thermovision infrared-sensing camera to detect sites of excessive heat leakage.

## Progress:

The process of comparing the pre- and post-wear insulating values of the various liners is nearing completion. Some difficulty in interpreting the differences is being experienced owing to technical difficulties with the copper hand during the original measurements. Errors caused by the malfunction are currently being estimated by remeasuring new samples similar to the original liners and by reanalyzing the power requirements in the original measurements.

**Presentations:**

None.

**Publications:**

None.

| | |
|---|---|
| Program Element: | 6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE |
| Project: | 3E762777AB45 Environmental Stress, Physical Fitness and Medical Factors in Military Performance |
| Work Unit: | 048 Biomedical Impact of Military Clothing and Equipment Design Including the Selection of Crew Compartment Environments |
| Study Title: | Biophysical Study of POL Handwear |
| Investigators: | Clement A. Levell, Thomas Endrusick and Louis Strong, Ph.D. |

Background:

Suitable handwear for personnel handling POL products in the cold must meet several requirements which are frequently in conflict, i.e., it must provide adequate environmental protection, but allow sufficient hand dexterity to permit operation of gasoline pump handles and the like. US Army Natick Research and Development Command has undertaken a program to develop improved designs and insulating materials for POL handwear, and required copper hand evaluations of items with a new form of shell, combined with several experimental liners have been requested.

Progress:

Measurements of sectional and overall insulation values were made on the standard POL glove combined with a fine-fiber liner, and on the new POL glove form in combination with a synthetic single-faced pile (with nap facing both in and out), or with a urethane foam liner. All combinations were also evaluated with a standard 3-finger wool mitten next to the hand to check insulating benefits which might be obtained by adding this item. Overall insulating values for these systems are given in Table 1.

TABLE 1

Overall Insulating Value(clo) of POL Glove Systems

| Glove | Liner | without 3-finger mitten | w/3-finger mitten |
|---|---|---|---|
| Standard | Fine Fiber | 1.92 | 1.93 |
| New Form | Pile, nap inward | 2.16 | 2.22 |
| New Form | Pile, nap outward | 2.16 | 2.17 |
| New Form | Urethane Foam | 2.05 | 1.99 |

The 3-finger mitten did not greatly increase insulation value since the POL gloves and liners were not sized to accommodate this item. As a result, the material inside the glove was merely compacted when the mitten was used; i.e., dimensions were constrained by the POL glove. Consequently, insulation value, which is primarily a function of thickness, remained the same with the mitten added. It actually decreased slightly in the system with urethane foam, possibly because increasing the foam density increased heat conduction via the foam particles.

## Future Plans:

This study is completed. A physiological study to evaluate POL handwear protection while holding pump handles in cold environments is awaiting Human Use Committee approval. In the meantime, an attempt will be made to obtain information on local heat losses in the palm area, while holding such handles and compressing the insulation, the AGA infrared sensing camera in conjunction with a heated, sectional copper hand.

## Presentations:

None.

## Publications:

None.

| | |
|---|---|
| Program Element: | 6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE |
| Project: | 3E762777AB45 Environmental Stress, Physical Fitness and Medical Factors in Military Performance |
| Work Unit: | 048 Biomedical Impact of Military Clothing and Equipment Design Including the Selection of Crew Compartment Environments |
| Study Title: | Development of a Controlled, Heated Sectional Hand and Foot |
| Investigators: | John R. Breckenridge, Leander A. Stroschein and Clement A. Levell |

## Background:

The single circuit copper men, sectional copper man, single circuit copper hands and feet and sectional copper hand and foot are essential to our work on protection evaluation and prediction of environmental tolerance limits and casually risk. Our ability to interpret the values measured with these devices, coupled with the increased precision of our measurements with these devices and the increasing difficulty of carrying out studies involving experimental exposures of human subjects has placed a tremendous work load on these items.

A program was initiated in FY75 to begin replacement of several of the electrically-heated devices used for insulation and evaporative transfer measurements. Most of these devices, e.g., copper manikins sectional hands and feet, etc., have been in service for more than 15 years and are becoming structurally or electrically defective.

## Progress:

A schedule of priorities has been developed for planned replacement of several items by FY 1982. Much of the equipment involved is employed in support of NARADCOM development programs and is not duplicated elsewhere in the US.

During FY 1977, the first of these replacement items, a pair of 26-section copper feet with vastly improved design characteristics were completed under contract with Utah Biomedical Test Laboratory. A controller for this device was also delivered under a separate contract. This controller, in combination with off-the-shelf devices such as digital voltmeters, scanners, and a Hewlett Packard 9825 calculator, has the capability of automatically controlling the new feet plus existing and contemplated devices, including the copper men; the system can also perform on-line calculations, tabulation of data, and plotting of trends. Work is currently under way to make the system operational. When complete, this new acquisition should represent a giant step forward and permit more rapid evaluation of clothing and military equipment items with much less operator time than is currently required.

Programming of the 9825 calculator to provide control and measurement capability for operation of sectional hands and feet is continuing. On completion of this software, operational characteristics, etc. of the new sectional copper feet will be determined. Remote terminals for control and measurement operations on at least four copper manikins is planned; progress in this automation procedure will depend on availability of funds for equipment purchase, and time needed for systems checking and programming.

Presentations:

None.

Publications:

None.

## LITERATURE CITED

1. Goldman, R. F. The arctic soldier: possible research solutions for his protection. Proceedings of Fifteenth Alaskan Science Conference, College, Alaska, 1964.

## IV FOOTWEAR STUDIES

### Background:

Like the hands, the feet of an inactive soldier cannot be adequately protected in a cold environment because of both the very low blood flow, hence low heat input, to these extremities, and the inability to provide high insulating value around the toes. The two outer digits generally decrease most rapidly in temperature once there is vasoconstriction (the temperature of the heel is usually only a few degrees higher); temperature below 50°C (40°F) after only about 1½ hours exposure for men at rest at -30°C (-20°F) even with the best available footwear. The inactive tolerance time in any type of cold weather footwear can apparently not be extended greatly by adding more layers of body clothing, since these produce only marginal improvements in insulation over that for a complete cold weather ensemble. Tolerance time can be extended if the inactive soldier enters a sleeping bag in order to better match heat loss to his heat production (the intermediate LINCLOE bag provides the clothed soldier over 50% more insulation than the complete 4.3 clo arctic uniform). It is also possible to maintain adequate foot blood flow for extended periods by heating the feet with only 10 Watt of power, provided no foot temperature is allowed to drop below 15°C (60°F) (1). However, these two measures for prolonging tolerance cannot obviously be considered as practical solutions to the footwear protection problems of infantry soldiers.

Some idea of the difficulties of protecting the feet, and particularly the toes, may be obtained by examining the insulating values for the standard cold-dry insulated boot, which is a bulky 3 pound item. Its overall insulating value is only 1.7 clo, the toecap provides only 1.8 clo, and the heel 1.9 clo, these values are only 30% of those provided over the torso by an Arctic uniform, and 25% of the overall protection provided by a good cold weather sleeping bag.

A 12-section copper foot has been in constant use for over 15 years in evaluating footwear items for US Army Natick Research and Development Command designers and developing values for use in prediction of operational

tolerance time for troops in the cold. The results obtained with the device have provided guidance for improving the insulation balance of experimental footwear and to indicate progress, although marginal to date, in producing more insulative constructions, especially for the toe, tongue and heel areas.

## LITERATURE CITED


1. Goldman, R. F. The arctic soldier: possible research solutions for his protection. Proceedings of Fifteenth Alaskan Science Conference, College, Alaska, 1964.

| | |
|---|---|
| Program Element: | 6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE |
| Project: | 3E762777AB45 Environmental Stress, Physical Fitness and Medical Factors in Military Performance |
| Work Unit: | 048 Biomedical Impact of Military Clothing Equipment Design Including the Selection of Crew Compartment Environments |
| Study Title: | Evaluation of 12 Footwear Items on Copper Feet |
| Investigators: | Onofrio F. Compagnone and Ralph F. Goldman, Ph.D. |

## Background:

To cover their developments of military prototypes and assessment of commercial footwear items, etc., US Army Natick Research and Development Command (NARADCOM) has requested sectional measurements of insulation value on 12 separate footwear items when they become available for test.

## Progress:

Six footwear items, namely, four version of commercial US and Canadian mukluks with felt bootee inserts and two standard US black cold-wet insulated boots produced by one manufacturer, were measured under this program. The mukluks were of the rubber bottom, leather upper variety; three of them were well-known, highly regarded Canadian types, and one was a US version with a modified box toe. The US insulated boots, which were pre-production samples obtained from the manufacturer, were compared with 1966 "control" sample of this boot. Insulation values for five of the more critical foot sections, and overall insulation, are summarized in Table 1.

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ANNUAL PROGRESS REPORT, FISCAL YEAR 1977.(U)
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Table 1. Sectional Insulating Values and Overall Insulation for Six Cold Weather Footwear Items (clo units)

COMMERCIAL MUKLUK TYPE

| Section | U.S. #1 | Canadian #1 | Canadian #2 | Canadian #3 |
|---|---|---|---|---|
| Toecap | 1.38 | 1.25 | 1.42 | 1.31 |
| Foresole | 1.77 | 1.47 | 1.75 | 1.55 |
| Tongue | 2.43 | 2.39 | 2.26 | 2.09 |
| Heel | 2.10 | 1.96 | 2.01 | 1.75 |
| Ankle | 2.67 | 2.72 | 2.63 | 2.35 |
| Overall | 2.03 | 1.96 | 2.01 | 1.82 |

US COLD-WET INSULATED

| | Sample #1 | Sample #2 | Control |
|---|---|---|---|
| Toecap | 1.30 | 1.53 | 1.46 |
| Foresole | 2.54 | 2.57 | 2.34 |
| Tongue | 1.16 | 1.20 | 1.34 |
| Heel | 1.43 | 1.59 | 1.88 |
| Ankle | 1.64 | 1.68 | 2.00 |
| Overall | 1.53 | 1.63 | 1.82 |

Some of the variation between values for the respective section with the mukluk type boots was attributed to differences in fit on the copper foot; a snug fitting boot will generally show less insulation value than a looser version. Canadian #3 was an original version which was copied to some extent in Canadian boots #1 and #2; the latter two generally had higher insulating values, but were one size larger and about 250 grams heavier. The pre-production insulated boot samples (#1 an experimental version, and #2 the type proposed for manufacture) were tighter fitting than the 1966 control sample, and for that reason showed lower sectional values than the control. Notable exceptions were the higher toecap and

foresole values with boot #2. These two sections determine the protection over the critical toe areas; the higher values indicate better protection for the toes. Probably, improved techniques have been devised for forming the insulating materials over the sharply curved toecap and its juncture with the foresole.

Six additional sectional footwear evaluations remain to be performed under this NARADCOM contract. The types of footwear to be measured are unknown at this time.

Presentations:

None.

Publications:

None.

## V. MATERIALS EVALUATIONS

### Background:

Protective clothing items are fabricated from materials. The thermal properties of these materials, as measured on heated and/or sweating flat plate devices, frequently are controlling parameters for the physiological effects of items made from them, and identification of unsatisfactory insulation and/or evaporative transfer characteristics at the materials selection level can dramatically reduce the costs involved in fabrication and physiological evaluation of protective items per se. More promising candidate materials and fabrication concepts can also be identified but, while unsatisfactory materials never make up into superior end items, it is unfortunately frequently difficult to realize the advantages of superior materials in the end item ultimately fabricated from them. While US Army Natick Research and Development Command (NARADCOM) has an extensive screening program for the insulation characteristic of materials, we perform detailed analyses of evaporative permeability ratios ($i_m$/clo), of various reflective materials lay ups and the like, usually under a reimbursement funding arrangement from NARADCOM.

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| Program Element: | 6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE |
| Project: | 3E762777AB45 Environmental Stress, Physical Fitness and Medical Factors in Military Performance |
| Work Unit: | 048 Biomedical Impact of Military Clothing and Equipment Design Including the Selection of Crew Compartment |
| Study Title: | (1) Evaluation of the Physiological Benefits of Reflective Insulation; (2) Analysis of Improved Reflective Materials for Arctic Protection |
| Investigators: | Thomas Endrusick, John R. Breckenridge and Clement A. Levell |

**Background:**

Use of reflective insulation has long been suggested as a way to improve upon the usual linear relationship between insulation clo and thickness, with a one inch thickness of insulating material almost always affording 4 clo units of insulation on a flat surface. Newer, aluminized plastic ("space blanket") materials appeared to offer a unique opportunity to break the link between bulky, thick insulation materials and the high degree of protection against heat loss required in extreme cold environments. The theoretical basis for such protection is an intrinsic part of this Institute's expertise in dealing with problems of protection of the man in environmental extremes. Accordingly, a series of small scale evaluations have been conducted over the last few year.

**Progress:**

A long term study of the possible benefits of using reflective layers to reduce radiant heat transfer in cold weather clothing has been completed. Various systems comprising polyester battings, which normally permit considerable heat loss by radiation because of their highly porous structure, but which incorporate one or more reflective layers, were measured for insulation value on a guard ring flat

plate to determine the basic principles for application of these metallized layers. Systems of denser materials, such as woven fabrics and foams, were also measured to demonstrate the poor potential for reflectives with such materials, in which radiant exchange paths are largely non-existent. Two types of reflectives were employed: (1) films of mylar and polyvinylchloride with vacuum deposited metal on one or both faces and (2) fabrics with a thin metallic sheet pressed into the surface with sufficient force to fragment the metal; the latter had the advantage of being quite vapor permeable. The two types were equally effective in reducing radiant transfer and improving thermal insulation; however, both were inferior to solid aluminum foils of the household variety.

Studies of the optimal configuration and orientation of reflective layers showed that, as indicated from consideration of physical laws, the greatest increases in insulation were obtained when each batting layer had reflective surfaces facing its surface, i.e., two reflective layers facing each other across each batt. Typical flat plate results on uncompressed systems which demonstrate this principle are shown in Table 1.

Table 1. Diagrammatic Representation of Orientation[a] and Number of Reflective Layers in a 2-oz Polyester Batting System (Insulation values in clo units)

| Layer Identification | System Components (a) | (b) | (c) | (d) | (e) | (f) |
|---|---|---|---|---|---|---|
| 1.1 oz nylon | — | — | — | — | — | — |
| Metal-on-cloth reflective | b | | | | | |
| 2 oz polyester batt | □ | □ | □ | □ | □ | □ |
| Metal-on-cloth reflective | b | | | | | |
| 2 oz polyester batt | □ | □ | □ | □ | □ | □ |
| Metal-on-cloth reflective | b | | | | | |
| 1.1 oz nylon | — | — | — | — | — | — |
| clo | 3.47 | 3.45 | 5.07 | 5.10 | 5.11 | 6.91 |

a. Metal face orientation on reflective indicated by arrow direction

b. Non-metallized fabric used as a control

Similar increases in insulation could not, however, be sown in cold weather ensembles which contained liners fabricated as in system (f) above. At best, only a 12% increase in insulation was produced by the reflective layers. The reason for the large reduction in benefits was traced to the compression effects of the stitching used to hold the layers together; on the plate, stitching system (f) into 4 inch squares completely eliminated all effect of the reflectives. This stitching apparently compressed the batting, and greatly increased its density, so that there was little radiant exchange even without reflective layers, and therefore no potential for such radiation-blocking reflectives. Compression studies on a flat plate performed with a system like (f) clearly demonstrated this phenomenon and indicated that the role of the reflective layers was simply to restore the insulation loss caused by radiant exchange in batting layers. That is, the uncompressed batting system with non-reflective layers provided much less than the 4 clo/inch of thickness obtained with moderately dense fabrics. Changing to reflective layers in the batting system simply eliminated most of the radiant exchange and raised the clo/inch to a value only slightly less than for denser woven or knitted fabrics. Under compression, the batting system density was higher, and the clo/inch value with non-reflective layers was not as drastically reduced as in the uncompressed state. The clo/inch value with re-flectives approached a limiting value of 4.6, or 15% higher than the conventional 4 clo/inch value, as compression increased and thickness was reduced. Results of this phase of the study are shown in Table 2.

Table 2. Effects of Compression on Potential Benefits of Reflective Layers

| Reduction in Thickness (%) | Slope of Insulation Curve* (clo/inch) | | Total Insulation (clo) | | |
|---|---|---|---|---|---|
| | reflec. layers | non-reflec. layers | reflec. layers | non-reflec. layers | difference |
| 0(uncompressed) | 3.3 | 1.6 | 8.2 | 6.2 | 2.0 |
| 12.5 | 3.8 | 2.0 | 7.4 | 5.8 | 1.6 |
| 25 | 4.1 | 2.4 | 6.7 | 5.4 | 1.3 |
| 50 | 4.5 | 3.3 | 5.0 | 4.3 | 0.7 |
| 75 | 4.6 | 3.9 | 3.2 | 2.9 | 0.3 |

* change in clo value per inch change in thickness

The results are displayed graphically in figure 1.

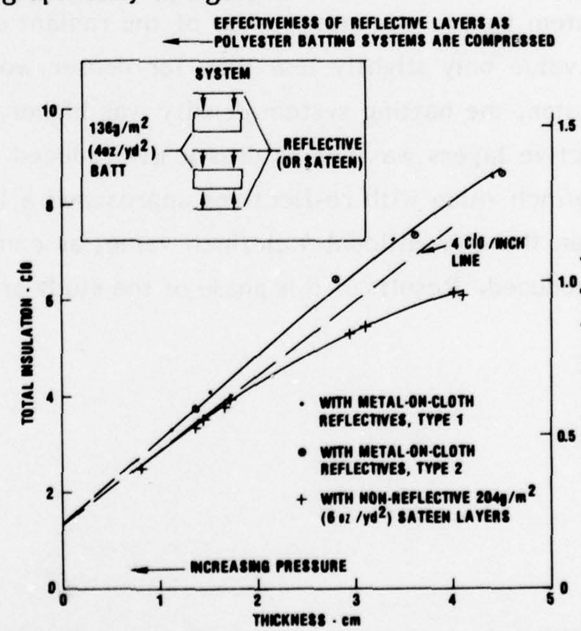


Figure 1. Reduction of insulation increase using reflective layers, as the ensemble is subjected to compression.

Systems employing corrugated net spacer materials next to the batting, to minimize reduction in batting thickness under load, showed promise, in flat plate studies, of solving the problems associated with stitching but were found to be excessively bulky for use in cold weather clothing. Other approaches, especially one introduced by a civilian manufacturer, have since shown greater promise of success. Despite the problems, reflective layer application is not considered a failure since such layers do, in most clothing applications, permit the use of low density, light weight materials without any serious sacrifice of protection. Once the fabrication and compression problems are resolved, there are many applications, such as in improved sleeping systems, where reflective layers could play an important role.

A Technical Report summarizing the findings of this study is being prepared. Additional studies of promising applications of reflective layers will be initiated in-house or in collaboration with US Army Natick Research and Development Command (NARADCOM) clothing developers.

Presentations:

Breckenridge, J. R. and R. F. Goldman. Evaluation of thermal insulation benefits from reflective layers in fabric systems. Combat Clothing and Equipment Working Party, NATO, Brussels, Belgium, 6-10 June 1977.

Publications:

None.

| | |
|---|---|
| Program Element: | 6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE |
| Project: | 3E762777AB45 Environmental Stress, Physical Fitness and Medical Factors in Military Performance |
| Work Unit: | 048 Biomedical Impact of Military Clothing and Equipment Design Including the Selection of Crew Compartment Environments |
| Study Title: | Increasing Evaporative Surface Area |
| Investigators: | John R. Breckenridge, Thomas Endrusick and Louis Strong, Ph.D. |

Background:

In hot humid environments, the maximal amount of evaporative heat ($E_{max}$) which can be dissipated is a function of the insulation (clo) and permeability index ($i_m$) of the clothing, i.e., of the evaporative index $i_m$/clo. The $i_m$ for clothing appears to be limited to approximately 0.45 in still air, although it does increase to perhaps 0.6 with moderate winds. Thus, clothing imposes a serious limitation on the level of activity which may be continued indefinitely in a given environment without the soldier eventually reaching physiological limits of heat storage. The present investigation was the first in a series of attempts to increase the evaporative index, ($i_m$/clo), and thus the potential for heat dissipation, by increasing the clothing area for evaporative heat transfer, and hence the value of $i_m$, without increasing the insulating (clo) value.

Progress:

A fabric system made to have a corrugated surface by stitching flexible metal conductors to the underside at 1/4 inch intervals was compared for $i_m$/clo with conventional fabrics of the same material. The metal conductors were employed to conduct heat readily to the covering fabric, thus maintaining its surface at nearly plate temperature. Theoretically this special configuration, when

wetted, would provide more cooling since the water evaporation rate would be increased in proportion to the increase in surface area caused by the corrugations. At the same time, little increase in clo value should result since the entire fabric surface was maintained near the temperature of the flat plate. Preliminary results (average) for the increased evaporative surface area (IESA) system and for the base cotton fabric used in the IESA, both measured in direct contact with the dry/wet plate are given in Table 1.

TABLE 1. Insulation (clo) and Evaporative Cooling Coefficients ($i_m$/clo) Using the Concepts of Increasing Surface Area

| | clo | $i_m$ | $i_m$/clo |
|---|---|---|---|
| IESA | 0.68 | 0.72 | 1.06 |
| Cotton Only | 0.57 | 0.56 | 0.98 |

The results show that use of the metal conductors was not entirely successful in maintaining clo constant. However, $i_m$ was increased by almost 30% by using the corrugated structure in IESA, and the evaporative index $i_m$/clo was increased by 8%. These results were unfortunately not consistent with those for systems with additional underlying layers.

Work is continuing to clarify the reasons for discrepancies and to assess the merits of an IESA layer or layers in a multiple-fabric system.

**Presentations:**

None.

**Publications:**

None.

| | |
|---|---|
| Program Element: | 6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE |
| Project: | 3E762777AB45 Environmental Stress, Physical Fitness and Medical Factors in Military Performance |
| Work Unit: | 048 Biomedical Impactof Military Clothing and Equipment Design Including the Selection of Crew Compartment Environments |
| Study Title: | Improvement of Auxiliary Heating Efficiency by Employing Reflective Layers |
| Investigators: | John R. Breckenridge and Thomas Endrusick |

Background:

Auxiliary electrical heating has been considered for many years as a means of improving the protection of the hands and feet in cold environments. If such heating could be applied directly at the skin surface, each watt of power would reduce the heat dissipation one watt, thus in effect increasing the insulating value of the skin covering. In actual practice, however, auxiliary heating is never 100% efficient since a small spacing between the heating wires and skin is unavoidable. The actual efficiency is given simply by the ratio of the insulation value outside the heat source divided by the total insulation from the skin out; efficiencies usually range from 50% to 80% depending on the method of incorporating the heaters into insulating layers.

In considering use of auxiliary heating within cold weather handwear incorporating low density polyester battings and other porous constructions, it appeared that heating efficiency could be improved by increasing the insulating value of the material outside the wiring. Our studies of the benefits of reflective layers used with low density or porous materials (reported elsewhere under this work unit) suggested that improved efficiency could be obtained by using such reflectives as radiation barriers in the handwear. A flat plate study to establish the magnitude of benefit and optimal placement of reflective layers in handwear systems was accordingly scheduled.

Progress:

This study has not commenced owing to higher priority uses for the flat plate. However, the heater grid for supplying auxiliary power has been constructed and tested; it is highly porous and will not interfere with convective or radiant exchanges.

Various fabric systems, with and without reflectives, will be employed in conjunction with auxiliary electrical heat to determine whether or not use of reflectives can be used to improve heating efficiency, and to indicate the system and layer configurations which produce the best results. The most promising designs will be incorporated into handwear and studied on the copper hand.

Presentations:

None.

Publications:

None.

| | |
|---|---|
| Program Element: | 6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE |
| Project: | 3E762777AB45 Environmental Stress, Physical Fitness and Medical Factors in Military Performance |
| Work Unit: | 048 Biomedical Impact of Military Clothing and Equipment Design Including the Selection of Crew Compartment Environments |
| Study Title: | Comparison Study of NATO Material Evaluation Techniques |
| Investigators: | Thomas Endrusick and John R. Breckenridge |

Background:

A detailed biophysical study was conducted on recently developed NATO combat and cold weather fabrics using the heated, dry/sweating flat plate technique. These studies are also being carried out in the UK, Canada, Germany and France in support of efforts to develop standardization of materials evaluation techniques which should lead to greater standardization of end items. The results obtained will be utilized to further develop relevant physiological heat transfer data. Once international confidence in the comparability of materials develops, it should be easier to encourage national manufacture, from in-country materials, of combat clothing and personal life support equipment items which meet an agreed standardization criterion.

Progress:

The members of the NATO Combat Clothing and Equipment Working Party (CCEWP) who furnished materials were the United Kingdom, Denmark and Germany. These materials were compared to US standard combat materials of similar design. Future evaluations conducted on combat and cold weather materials from other NATO members are expected to further contribute to the development of effective clothing system and to NATO standarization. Results are summarized in Table 1.

Table 1. Flat Plate Results on Various NATO Materials

| Windproof Materials | $g/m^2$ | clo | $i_m$ | $i_m$/clo |
|---|---|---|---|---|
| Std UK 8003C Windproof gabardine | 179 | 0.63 | 0.39 | 0.62 |
| US Std wind resistant poplin | 208 | 0.57 | 0.38 | 0.67 |
| UK ventile L-28 | 295 | 0.58 | 0.29 | 0.50 |
| **Cold Weather Liners** | | | | |
| UK D4531E quilted liner | 279 | 1.87 | --- | --- |
| US Std field coat liner | 206 | 1.96 | --- | --- |
| **Wool Combat Materials** | | | | |
| Std UK 8026B wool flannel | 289 | 0.85 | 0.52 | 0.61 |
| US wool/nylon | 373 | 0.72 | 0.51 | 0.71 |
| German 8305-126 wool | 408 | 0.63 | 0.35 | 0.56 |
| **Fatigue Clothing Materials** | | | | |
| 8305-117 Std German combat suit material | 323 | 0.59 | 0.38 | 0.64 |
| Danish combat cloth | 303 | 0.58 | 0.40 | 0.69 |
| 8014C Std UK combat suit material | 308 | 0.71 | 0.41 | 0.58 |

Flat plate evaluations will continue to be performed for NATO CCEWP members to assist them in standardizing operations of "sweating" flat plates, which several member nations now have available or planned for the future.

Presentations:

Breckenridge, J. R. and T. Endrusick. Comparison of thermal properties of NATO materials. Combat Clothing and Equipment Working Party, NATO, Brussels, Belgium, 6-10 June 1977.

Publications:

None.

| | |
|---|---|
| Program Element: | 6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE |
| Project: | 3E762777AB45 Environmental Stress, Physical Fitness and Medical Factors in Military Performance |
| Work Unit: | 048 Biomedical Impact of Military Clothing and Equipment Design Including the Selection of Crew Compartment Environments |
| Study Title: | Onset of Thermal Discomfort |
| Investigators: | Lucy Graff, Fred R. Winsmann and Ralph F. Goldman, Ph.D. |

## Background:

The onset of thermal discomfort is usually established by "Comfort Vote", but it appears that only about 80% of the population can be ideally comfortable at a given ambient temperature condition. We believe the problem lies, as with subjective reported perceived exertion, in a difference in the focus of attention between local, central or overall effects. The extremities, particularly toes and fingers are the first to be affected by cool discomfort, but the air temperature at which a resting subject first experiences cool fingers or toes (as a result of vasoconstriction a physiological mechanism for heat conservation, being invoked) has not been studied. With increasing concern regarding the climate within combat vehicles, as well as for the need to conserve energy and the imminent requirement to adjust summer and winter thermostat settings in Army buildings, investigation of the onset of thermal discomfort seemed worthwhile.

## Progress:

The study has been completed. It was conducted in a climatic chamber over a 5-day period using 8 volunteers ranging in age from 19 to 26 yrs. Two different ballots were used for recording the comfort responses of the subjects; one was used to assess the comfort sensation of the toes, fingers, and torso by marking an

arrow on a straight line which had no verbal clues except the words "hot" and "cold" at either end of the scale. The second ballot contained a numerical scale with verbal descriptions; hot corresponded with 7, warm-6, slightly warm–5, neutral-4, slightly cool-3, cool-2, and cold-1; this ballot was used to determine the subjects overall comfort. Thermocouples were placed on the 2nd and 5th fingers and 1st and 5th toes to record these temperatures every 2.5 minutes during exposure. All subjects wore standard Army fatigues with dress cotton socks and black low quarter shoes.

Each subject was exposed for 120 minutes each day for 5 days; the first 30 minutes were at 24.4°C (76°F), which represents a preferred comfort point for most people. This 30 minutes established equilibrium and served as a baseline measurement. The remaining 90 minutes was spent at a different lower temperature each day; 17.2°, 18.3°, 19.4°, 20.6° or 21.7°C (63°, 65°, 67°, 69°, or 71°, respectively presented randomly during the 5-day period. Comfort ballots were filled out periodically during the 30-minute control temperature period, and then every 15-minutes duirng the remaining 90-minute period. Subjects sat in chairs around tables either playing cards, watching TV, or talking. They were not permitted to stand, eat, smoke, drink, or discuss the thermal environment in any way.

The results showed the expected decline, with time, in finger and toe temperatures as the ambient temperature dropped; the corresponding comfort vote generally indicated increased discomfort with lower temperature. Figure 1 shows the 2nd and 5th finger temperature corresponding to a given comfort vote and Figure 2 presents the comfort vote corresponding to the 5th and 1st toe temperature.

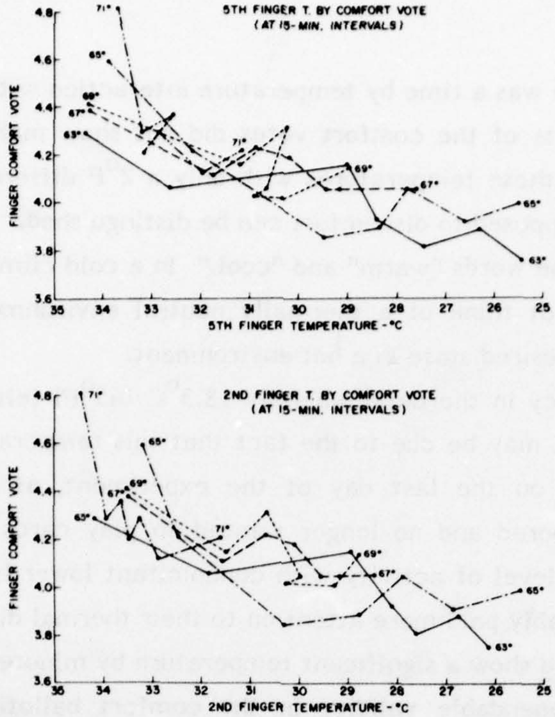


Figure 1. Relationship between 2nd (and 5th) finger temperature and comfort vote during exposure.

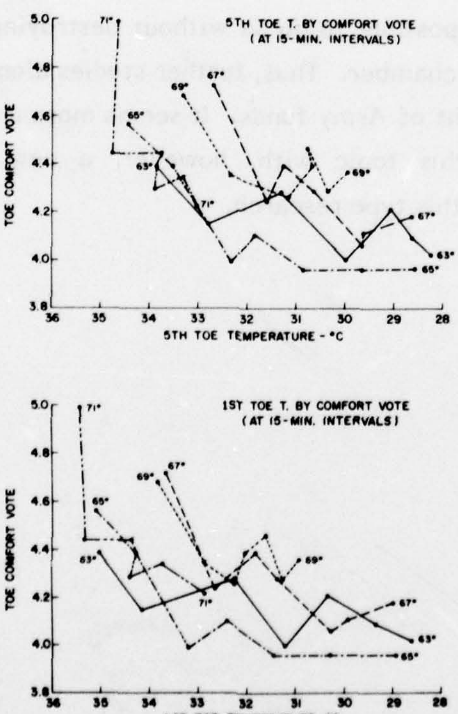


Figure 2. Relationship between 1st (and 5th) toe temperature and comfort vote during exposure.

Statistically, there was a time by temperature interaction with finger and toe temperatures, but results of the comfort votes did not show marked differences tinguishability between these temperatures with only a 2°F difference. However, feelings of comfort as opposed to discomfort can be distinguished. This may be due to the connotation of the words "warm" and "cool." In a cold climate people want to be warm, they do not think of a thermally neutral environment; conversely, "cool" seems to be the desired state in a hot environment.

The one discrepancy in the data, whereby 18.3°C (65°F) felt cooler than all the other temperatures, may be due to the fact that this temperature, by random chance, was presented on the last day of the experiment, at which time the subjects were feeling bored and no longer wanted to play cards (which possibly meant a slightly lower level of activity with concomitant lower heat production); consequently, they probably paid more attention to their thermal discomfort.

Since this study <u>did</u> show a significant temperature by minute interaction, but <u>did not</u> show much dependable validity in the comfort balloting, any further investigation should deal with this problem. However, there are many variables which affect the comfort vote; if possible, these should be separated and tested individually but it seems impossible to do so without destroying the reality of the world outside of the testing chamber. Thus, further studies along these lines do not seem a reasonable investment of Army funds. It seems more appropriate to simply follow the literature on this topic with, however, a new awareness of the limitations and problems of this type research.

<u>Presentations:</u>

None.

<u>Publications:</u>

None.

Program Element: 6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE

Project: 3E762777AB45 Environmental Stress, Physical Fitness and Medical Factors in Military Performance

Work Unit: 048 Biomedical Impact of Military Clothing and Equipment Design Including the Selection of Crew Compartment Environments

Study Title: Evaluation of a "Ventilating" Gym Shoe

Investigators: Fred R. Winsmann, Ralph F. Goldman, Ph.D., L. Shubitowski and Sally Cutler

**Background:**

A new "ventilating" tennis shoe was designed by a commercial manufacturer "to keep the feet cooler and drier" and thus help prevent the occurrence of athlete's foot and similar infections associated with hot, sweaty socks and footwear. It has been clearly shown that an increase in moisture in footwear causes an increase in athlete's foot and other related skin diseases of the foot (1,2). Experimental footwear has been designed in the past which attempted to reduce moisture in the foot by increasing air circulation around the foot, thus increasing evaporative processes; previous studies involving experimental rubber and leather combat boots have shown that it is not feasible to have a self-pumping air mechanism incorporated in a boot (3,4). The approach to solving the moisture build-up problem in the new "ventilating" tennis shoe was to design a low cut sneaker with ventilating holes punched in the bottoms and sides. The theory was that, while walking or running, air would be pumped in through the bottom holes, circulated around the feet, and forced out the side holes resulting in drier, cooler, and more comfortable feet.

**Progress:**

This study has been completed. Four laboratory personnel volunteered to walk on a treadmill at 2.5 mph, 0% grade with the new "ventilating" shoes, with

either both air inlets intact, or with the right or left, or both air inlets blocked, as controls; the subject did not know which shoes (neither, both, or right or left) were functioning and which were not. Exposure time was one hour at 35°C (95°F), 27% r.h. for 4 separate trials wearing the same pair of shoes, but with a different blocked condition for each trial. The holes in the bottom of the shoes were blocked by insertion of a thin, flexible plastic insole between the insole and bottom of the shoe. The subjects wore shorts and a new pair of tube socks for each trial.

Foot temperatures were measured by placing thermocouples on the big toe and instep of each foot and were continuously recorded during the trials. A comfort vote ballot, for each foot, was presented five times during each trial (0, 15 min, 30 min, 45 min, 60 min). Sweat absorption by the footgear was measured by weighing the socks and insoles of the shoes before and after each run. Heart rate was also measured, but only as a precaution against heat strain.

A two-way analysis of variance was performed on the resting subjective comfort and sweat production data (subject X condition); a three-way analysis of variance was performed on all data from the subjective comfort scale (subject X condition X time interaction). Analysis showed that there was no statistical difference in the sweat pick up of the socks and insoles in either foot in any of the four conditions. There was also no statistical differences in the final foot temperatures recorded. Although the temperature spread was quite marked at the start of testing, by the end of the hour all four points were within 1°C of each other. Although there was a statistically significant difference in the comfort questionnaire it was opposite from the expected effect, i.e. subjects reported being more comfortable wearing the blocked shoe as compared to the experimental ventilated one.

It is obvious from the results that the new design does not produce the desired effect. There were no significant trends shown in sweat retention or temperature increase, regardless of the shoe condition. Subjectively, there tended to be a reversal effect in that the blocked shoe was often reported to be more comfortable than the open experimental shoe. This may be due to an intake of warmer air from the surface of the treadmill with the unblocked shoe, since we measured a 1°C difference between ambient air temperature and air temperature just above the surface of the treadmill, and the treadmill belt itself was quite a bit warmer.

As shown in this evaluation, and in previous research cited on ventilating footwear, this approach (which surfaces with some regularity as a "new" idea) appears doomed to failure by the disparity between practical air volumes that can be delivered and those that are required for any practical evaporation of moisture from the foot (3,4).

Presentations:

None.

Publications:

None.

## LITERATURE CITED


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2. Taplin, D., N. Zaias and G. Rebell. Environmental influences on the microbiology of the skin. Archives of Environmental Health. Vol. II, 546-550, October 1965.

3. Winsmann, F. R. Study of an experimental ventilated insulated boot with built-in pump. Research Study Report FPB-1, Environmental Protection Research Division, Natick, MA, 1957.

4. Woodcook, A. H. and R. L. Pratt. Ventilation of insulated boots. Technical Report. EP-135. Environmental Protection Research Division, Natick, MA, 1960.

(83049)

| RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY | | 1. AGENCY ACCESSION* | 2. DATE OF SUMMARY* | REPORT CONTROL SYMBOL |
|---|---|---|---|---|
| | | DA OB 6140 | 77 10 01 | DD-DR&E(AR)636 |

| 3. DATE PREV SUM'RY | 4. KIND OF SUMMARY | 5. SUMMARY SCTY* | 6. WORK SECURITY* | 7. REGRADING* | 8a. DISB'N INSTR'N | 8b. SPECIFIC DATA-CONTRACTOR ACCESS | 9. LEVEL OF SUM |
|---|---|---|---|---|---|---|---|
| 76 06 15 | D. Change | U | U | NA | NL | [X] YES [ ] NO | A. WORK UNIT |

| 10. NO./CODES:* | PROGRAM ELEMENT | PROJECT NUMBER | TASK AREA NUMBER | WORK UNIT NUMBER |
|---|---|---|---|---|
| a. PRIMARY | 6.27.77.A | 3E762777A845 | 00 | 049 |
| b. CONTRIBUTING | | | | |
| c. ~~XXXXXXXX~~ | CARDS 114f | | | |

11. TITLE (Precede with Security Classification Code)*

(U) Factors Predisposing to Cold Injury (22)

12. SCIENTIFIC AND TECHNOLOGICAL AREAS* 002300 Biochemistry; 002600 Biology; 003500 Clinical Medicine; 005900 Environmental Biology; 012900 Physiology

| 13. START DATE | 14. ESTIMATED COMPLETION DATE | 15. FUNDING AGENCY | 16. PERFORMANCE METHOD |
|---|---|---|---|
| 10 01 | CONT | DA | C. In-House |

17. CONTRACT/GRANT

a. DATES/EFFECTIVE: EXPIRATION:

b. NUMBER:* NOT APPLICABLE

c. TYPE: d. AMOUNT:

e. KIND OF AWARD: f. CUM. AMT.

| 18. RESOURCES ESTIMATE | | a. PROFESSIONAL MAN YRS | b. FUNDS (In thousands) |
|---|---|---|---|
| FISCAL YEAR | PRECEDING 77 | 5.3 | 65 |
| | CURRENT 78 | 1.3 | 42.7 |

19. RESPONSIBLE DOD ORGANIZATION

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20. PERFORMING ORGANIZATION

NAME:* USA RSCH INST OF ENV MED

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PRINCIPAL INVESTIGATOR (Furnish SSAN if U.S. Academic Institution)

NAME:* HAMLET, Murray P., D.V.M.

TELEPHONE: 955-2865

SOCIAL SECURITY ACCOUNT NUMBER:

ASSOCIATE INVESTIGATORS

NAME: BERBERICH, Joel J., CPT, MSC

NAME: 955-2863

DA

21. GENERAL USE

Foreign Intelligence Not Considered

22. KEYWORDS (Precede EACH with Security Classification Code)*

(U)Cold Injury; (U)Dehydration; (U) $VO_2$ max; (U) Hypovolemics

23. TECHNICAL OBJECTIVE,* 24. APPROACH, 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)

23. (U)Total allied casualties due to cold injury in World Wars I, II and Korea exceeded one million cases. Four integrated studies are planned to elucidate factors predisposing to cold injury and ultimately reduce its incidence: dehydration, physical fitness, fatigue and shock. It has not been demonstrated whether dehydration, a common cold weather occurrence, adversely affects extremity cooling curves. The state of physical fitness more than likely will have a beneficial effect on peripheral cooling rates. Conversely, fatigue may well have an adverse affect. The fourth study will determine the affect of shock on predisposing the wounded to hypothermia and frostbite.

24. (U)Hand cooling of human subjects before and after an extensive physical training program will identify changes in cooling and rewarming rate after physical training. In a second study subjects will be dehydrated to 5% of body weight. Cooling and rewarming responses before and after dehydration will be monitored. The third study in which subjects are fatigued by heavy exercise and/or sleep deprivation will proceed next quarter.

25. (U) 76 10 - 77 09 Six subjects were trained in 1976. In a standard cold test, their hands were significantly warmer after training. No change was seen in 3 control subjects. Additional data were gathered on four trained and six control subjects in 1977. Using the same cold test, twelve resting subjects had significantly colder hands after dehydration. No change was seen in 12 control subjects. Data were also gathered for 12 exercising dehydrated and control subjects.

*Available to contractors upon originator's approval

DD FORM 1 MAR 68 1498 PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE. DD FORMS 1498A, 1 NOV 65 AND 1498-1, 1 MAR 68 (FOR ARMY USE) ARE OBSOLETE



* U.S. GPO: 1974-540-843/8691

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|---|---|
| Program Element: | 6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE |
| Project: | 3E762777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance |
| Work Unit: | 049 Factors Predisposing to Cold Injury |
| Study Title: | The Effects of Physical Fitness on Extremity Temperature |
| Investigators: | Donald E. Roberts, Ph.D., James J. Jaeger, CPT, MSC, Ph.D. and Joel J. Berberich, CPT, MSC, Ph.D. |

<u>Background:</u>

In most studies of acclimatization to cold, the response to cold has become intermingled with the response to both work and cold. Several investigators have attempted to ascertain the effect of changes in physical fitness and separate them from the response of a cold exposure. Almost all of the studies have used some type of training program and a standard cold stress which involves a nude subject residing in a cold environment for some time period (1,3,11).

Adams and Heberling (1,11) have shown in two separate studies that physically fit subjects tended to have a higher control skin temperature and a lower core temperature. The changes in physical fitness levels were estimated by a fitness index and are of minimal value for comparison with maximum levels of oxygen consumption (max $\dot{V}O_2$).

In a study by Keatinge (13), there was no documentation of physical fitness changes and training was performed during cold exposure. These studies (1,13) were somewhat different in the temperatures used and in the duration of cold exposure, but both had similar results. They both reported elevated skin temperatures and reduced core temperatures during cold exposure; however, the heat output (metabolic rate) was different for the two groups.

Hammel et al. (10) have shown in a study involving a five week training program with a cold group and a warm group, that conditioning had no apparent

effect on central or peripheral body temperatures. The conditioning raised the metabolic rate in the warm environment as well as in the cold environment and caused an increase in tissue conductance ( $H_{loss}$ Skin/Tr-Tmw) during cold exposure.

Hellstrom (12), using a small group of subjects, was unable to show any relationship between max $VO_2$ and skin temperatures during test in a cold environment. However, Fusco and Gatin (8) have shown that training will increase tolerance to a cold stress.

Based on these studies, it appears that there may or may not be an elevated skin temperature and decreased core temperature following training, but changes in metabolism and blood flow to the periphery do occur.

The effect of exercise during cold exposure on rewarming has also been investigated. Andersen et al. (2) have shown, in a study involving outdoor and indoor workers, that outdoor workers tend to rewarm the periphery faster than indoor workers. In both groups, the metabolic rate during exercise in the cold is elevated. Stromme et al. (16), in a study using students, fishermen, and lumberjacks, showed the outdoor workers rewarming the skin faster during exercise in the cold than did the indoor workers. No physical fitness measures were taken, but the lumberjacks were considered extremely fit. Hellstrom et al. (12) have shown that untrained subjects require the use of 40-65% of aerobic capacity to rewarm fingers when exposed to zero degrees C. The time course of rewarming was slower for toe temperatures than for finger temperatures and tended to show an increase when work was stopped.

The mechanism by which changes in physical fitness affects the skin temperature is not clearly defined. It has been reported that the sensitivity of the sweating mechanism during exercise is increased with improved physical fitness which would tend to cool the skin (12). The improved cardiac effects coupled with increased muscle vascularization with training may account for the increased peripheral blood flow and the resultant higher skin temperature.

The purpose of this study was to investigate the magnitude of skin temperature elevation following training and to determine its role in the maintenance of a warmer extremity during cold exposure.

Two groups of test subjects were tested for physical fitness (max $VO_2$) and responses to cold. The cold test involved a cold room ($0^{o}C$) exposure of 135 min. with one hand bare. Each subject was instrumented with 16 thermocouples on hands and other body areas, a rectal probe, and an ECG harness.

Following the initial testing, one group was trained (aerobic work) and the other group was allowed their normal activity (control group).

Comparisons of the area under the cooling curve for the thumb, little finger and middle finger on the exposed hand were made for each group.

Progress:

One group of subjects (6 trained, 3 non-trained) was run from April 1976 to July 1976. Based on the results of this group, another group was run from July 1977 to Sep 1977.

The preliminary results from the first group (1976) show the following from the trained group.

TRAINING GROUP DATA - GROUP 1

Area under hand cooling curve -- deg-min

| | Pre-training | Post-training | Significance level |
|---|---|---|---|
| thumb | 1115 ±93 deg-min | 2014 ± 187 deg-min | $p < 0.01$ |
| middle finger | 993 ± 135 deg-min | 1580 ± 199 deg-min | $p < 0.05$ |
| little finger | 902 ± 120 deg-min | 1483 ± 181 deg-min | $p < 0.05$ |

These data show a significant increase in the warmth of the hand following training (a 9% increase in max $VO_2$).

The control group and the trained group were not similar in that all trained subjects completed the 135 min cold test while none of the three control subjects did. Therefore, a second group was tested in 1977.

The second group (1977) consisted of three trained subjects who finished the cold test and one who did not. The control group consisted of four subjects who finished and two who did not finish. The data from this last group is not yet available, but will be used to augment the study run in 1976.

The temperature data from group 2 (1977) is awaiting analysis to determine the area under cooling curves and calculations of max $\dot{V}O_2$.

Presentations:

None

Publications:

None

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Program Element: 6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE

Project: 3E762777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance

Work Unit: 049 Factors Predisposing to Cold Injury

Study Title: Effects of Dehydration on Peripheral Cold Response

Investigators: Joel J. Berberich, CPT, MSC, Ph.D. and Donald E. Roberts, Ph.D.

Background:

The state of hydration has a definite effect on both central and peripheral heat transfer rates in a warm environment, even in a resting subject (1). Dehydration causes an increase in heating rate, in part due to a reduction in peripheral blood flow. Although dehydration should logically also have a pronounced effect on peripheral cooling rate, due in part to blood redistribution, altered osmolality and increased hematocrit, this effect has never been investigated. Since soldiers routinely may dehydrate in cold environment in the field, it is important to ascertain whether this dehydration adversely affects hand cooling and cold injury susceptibility. It might be predicted that mild exercise would potentiate the effects of dehydration in the cold. This prediction is based on the premise that increased cardiac and muscle blood flow shunted by exercise would further reduce blood flow to non-exercised extremities (2).

Progress:

To evaluate the effects of dehydration on response to peripheral cooling, a two phase study was conducted: resting men (phase I) and exercising men (phase II).

During Phase I, the effects of dehydration were evaluated by studying individual's responses to a prolonged cooling test in cold air before dehydration,

after dehydration, and following rehydration. Two groups of twelve subjects were studied in Phase I. One group was dehydrated to 5% body weight loss by mild exercise and restricted fluid intake, the other group (controls) underwent the same experimental procedures but maintained their fluid balance by drinking water *ad libitum*.

During Phase II the same design was followed except that while undergoing the prolonged air cooling test subjects also exercised at a low level. The rationale of Phase II was to evaluate the effect of moderate physiological demand in addition to dehydration on the subjects, as this is a more usual military situation.

The subjects were dehydrated by restricted fluid intake and mild exercise over a period of 3 days. Dehydration was monitored by body weight changes and by daily blood and urine chemistry profiles.

The cold test consisted of sitting in a chamber at $0^{o}C$ for 135 minutes dressed comfortably in military cold weather clothing. For the last two hours of this test, one bare hand was exposed to the cold air to assess hand cooling. During this test, 16 skin temperatures, rectal temperature and heart rate were continuously measured. Blood pressures and oxygen consumption were measured at intervals. During phase II of the study, the test subjects exercised on a bicycle ergometer for interrupted periods at low exercise levels.

Blood and urine chemistry analyses have been completed. Daily blood samples were analyzed for hematocrit, hemoglobin, serum sodium, potassium, chloride and osmolality. Twelve hour urine samples were analyzed for specific gravity, sodium, potassium, chloride and osmolality. All data (excluding temperature) have been reduced and entered onto computer discs for statistical analysis. The temperature data, which were acquired originally on magnetic tape, also have been submitted for computer analysis.

Based on the loss of body weight and rapid regain of weight, it appears that the test subjects were dehydrated during Phase I of the study (Table 1). Phase II body weight data are not available at the present time. The impact of this dehydration on hand cooling will be determined by comparing the temperature profiles during the cold tests (before and after dehydration and after rehydration). Completion of the analysis of the temperature data is anticipated in the near future.

Table 1. Percent Changes in Mean
Body Weights of Control and Dehydrated Subjects

| | Monday | Thursday | | Friday AM | | Friday PM | |
|---|---|---|---|---|---|---|---|
| Controls | Baseline | 0.19 | 0.46 | 0.47 | 0.44 | 0.32 | 0.47 |
| Dehydrated | Baseline | -4.2 | 0.31 | -1.72 | 0.23 | -0.32 | 0.28 |

Weights for dehydrated subjects on Thursday are after dehydration, on Friday 10 and 20 hours following rehydration. Controls experienced identical conditions except they were allowed fluid ad libitum. Values are mean + SEM, N = 12 each group.

Presentations:

None

Publications:

None

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(83050)

| RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY | 1. AGENCY ACCESSION* | 2. DATE OF SUMMARY* | REPORT CONTROL SYMBOL |
|---|---|---|---|
| | DA OB 6148 | 77 10 01 | DD-DR&E(AR)636 |

| 3. DATE PREV SUM'RY | 4. KIND OF SUMMARY | 5. SUMMARY SCTY* | 6. WORK SECURITY* | 7. REGRADING* | 8a. DISB'N INSTR'N | 8b. SPECIFIC DATA-CONTRACTOR ACCESS | 9. LEVEL OF SUM |
|---|---|---|---|---|---|---|---|
| 76 10 01 | H.Terminated | U | U | NA | NL | ☒ YES ☐ NO | A. WORK UNIT |

| 10. NO./CODES:* | PROGRAM ELEMENT | PROJECT NUMBER | TASK AREA NUMBER | WORK UNIT NUMBER |
|---|---|---|---|---|
| a. PRIMARY | 6.27.77.A | 3E762777A845 | 00 | 050 |
| b. CONTRIBUTING | | | | |
| c. XXXXXXXX | CARDS 114f | | | |

11. TITLE (Precede with Security Classification Code)*

(U)Behavioral Aspects of Physical Fitness Training(22)

12. SCIENTIFIC AND TECHNOLOGICAL AREAS*

012900 Physiology; 012500 Personnel Training & Evaluation

| 13. START DATE | 14. ESTIMATED COMPLETION DATE | 15. FUNDING AGENCY | 16. PERFORMANCE METHOD |
|---|---|---|---|
| 76 10 | 77 10 | D | C. In-House |

17. CONTRACT/GRANT

a. DATES/EFFECTIVE: EXPIRATION:

b. NUMBER:* NOT APPLICABLE

c. TYPE: d. AMOUNT:

e. KIND OF AWARD: f. CUM. AMT.

| 18. RESOURCES ESTIMATE | | a. PROFESSIONAL MAN YRS | b. FUNDS (In thousands) |
|---|---|---|---|
| FISCAL YEAR | PRECEDING 77 | 4. | 80 |
| | CURRENT | | |

19. RESPONSIBLE DOD ORGANIZATION

NAME:* USA RSCH INST OF ENV MED

ADDRESS:* NATICK, MASSACHUSETTS 01760

RESPONSIBLE INDIVIDUAL

NAME: DANGERFIELD, HARRY G., M.D., COL, MC

TELEPHONE: 955-2811

21. GENERAL USE

Foreign Intelligence Not Considered

20. PERFORMING ORGANIZATION

NAME:* USA RSCH INST OF ENV MED

ADDRESS:* NATICK, MASSACHUSETTS 01760

PRINCIPAL INVESTIGATOR (Furnish SSAN if U.S. Academic Institution)

NAME:* VOGEL, James A. Ph.D.

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SOCIAL SECURITY ACCOUNT NUMBER:

ASSOCIATE INVESTIGATORS

NAME: KOWAL, Dennis M. CPT, MSC

NAME:

DA

22. KEYWORDS (Precede EACH with Security Classification Code) (U)Aerobic Fitness; (U)Physical Fitness Training; (U)Perception of Effort; (U)Psychological Measures

23. TECHNICAL OBJECTIVE,* 24. APPROACH, 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)

23. (U)Physical fitness training in the Army has been largely developed on the basis of physiological and physical education concepts. Behavioral aspects have not received proper attention. These include compliance, adherence, motivation, attitudes, perception of effort, expectation of work ability and the psychological benefits of physical training.

24. (U)Specific studies will include: (1) determination if training and/or enhancement of fitness improves health, morale and sense of well being; (2) elucidation of possible differences in men and women in respect to perception of effort and expectation of work ability; (3) Develop new methods of enhancing training acceptance and compliance and (4) Relate attitudes and behavioral traits to training responsiveness and work ability.

25. (U) 76 10 - 77 09 In order to better understand differences in physical work performance between men and women, a study was carried out to determine if a.) women perceive physical effort differently than men; b.) does previous activity experience influence the perception of effort; and c.) how does acute and chronic training affect the perception of effort and ability for prolonged work in women. Preliminary analysis suggests that eprceived exertion in women is influenced by activity history and self concept prior to participation in aerobic training. The perceptual measures displayed a substantial interaction depending upon self concept/prior activity and group affiliation of these women. Psychological estimates of physical self concept improved for the previous low activity training group but not for the previous high activity training group when compared to controls. This Work Unit is being terminated. Further studies will be reported under Units 043 and 047.

*Available to contractors upon originator's approval

DD FORM 1 MAR 68 1498 PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE. DD FORMS 1498A, 1 NOV 65 AND 1498-1, 1 MAR 68 (FOR ARMY USE) ARE OBSOLETE

Program Element: 6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE

Project: 3E762777A845

Work Unit: 050 Behavioral Aspects of Physical Fitness Training

Study Title: The Effects of Activity Experience and Training on the Perception of Effort by Women

Investigators: Donald H. Horstman, Ph.D., Dennis M. Kowal, CPT, MSC, Ph.D. and Linda Vaughan, Ph.D.

Background:

Presently, about 5% of the workforce of the US Army is comprised of women, the highest percentage in peacetime history. This figure will increase substantially within the next few years with a projected contingency of 50,000 women soldiers. The role of the Army's women has also undergone drastic change; whereas previously confined to less physically demanding tasks (such as clerical work), all Military Occupation Specialties are presently available to women, with the exception of combat arms. With the prospect of increasing numbers of women serving in a greater variety of work roles, our interests have focused on the performance of prolonged physical work by women. Sustained performance of physical work is governed by two distinct factors: (a) one's capacity for work and (b) one's willingness to endure hard physical work. Capacity is objective in nature and dependent to a large extent upon genetic traits, but can be modified by other influences (primarily physiological), such as training, diet, and environment (1,2,3,4). Willingness to endure is more complex and subjective in nature, and probably governed by psychosocial factors (5,6,7,8).

Given this situation, the question is obvious: Are there physiological or perceptual differences between men and women that may obviate the latter from performing sustained heavy work. Currently available research provides little information. However, observations in our laboratory suggest that, when asked to perform tests which require a maximum voluntary contraction, women tend to score less than could be predicted on the basis of physiological indices, e.g., lean body mass. It has also been reported that women possess approximately half the

arm and shoulder strength of men, 3/4 the leg strengths, and 3/4 the aerobic capacity of the average man (9). Further we recognize that perception of work is related to experience. However, because society has often considered women incapable or it unfeminine, many women have not experienced strenuous physical work.

This study was designed to evaluate the following questions:

1. Do women perceive work differently than men and are the physiological and psychological factors related to work capacity the same for both groups?

2. How does prior experience influence the perception of effort and the capacity for sustained work performance?

3. Do women who have had high activity experience differ from those with low activity history in their response to training?

Progress:

Seventy-five women volunteers ages 18-22 served as subjects. They were assigned to one of 5 groups: Low previous activity, experimental (N = 14) and control (N = 15), high previous activity, experimental (N = 15) and control (15) and an intercollegiate athlete (high fitness) group (N = 15). The following measurements were made during the first and last week of the program. Anthropometric measurements were made of height and weight. Body composition was determined by measuring skin fold thickness with a Harpenden caliper at four anatomical sites: triceps, biceps, subscapular, and suprailiac. An interrupted treadmill test for maximal aerobic power ($\dot{V}O_2$ max) was performed following the procedure of Taylor (10). During the last minute of each run, the expired gas was collected into vinyl Douglas bags and analyzed for oxygen and $CO_2$ content. Subjects were monitored electrocardiographically during all runs. $\dot{V}O_2$ max was determined when the oxygen uptake did not increase with an increase in work load. At the end of each run the subject rated her perceptual response during the workload using Borg's report of perceived exertion (RPE). The RPE is a ratio scale from 6-20 with verbal labels: 6 = very, very light to 20 = very, very hard. The treadmill test for aerobic fitness was performed during the first week of study (Pre-training), a week later (Acute) and following the 12-week training program (Post-training). These replications

were performed to assess changes that may have occurred in both physiological and perceptual responses to maximal work, and the aerobic training program. The training program consisted of 12 weeks during which the women ran for progressively longer periods of time at a faster pace. Each week a 30 minute test run was performed to assess improvement in stamina and endurance. During the pre- and post-testing sessions the subjects were asked to complete a battery of cognitive and behavioral self-evaluation questionnaires designed to assess their attitude toward exercise, expectations of their physical capacity and performance.

Anthropometric measures are summarized in Table 1. The findings suggest that women engaged in an aerobic training program can expect to lose body fat but gain some weight even though they are maintaining high energy expenditures. This is attributed to the increase in caloric intake reported by the members of the training groups. Table 2 summarizes the physiological and perceptual responses to initial, acute and post training maximal exercise. The anticipated improvement in aerobic fitness is evident with improvement in $\dot{V}O_2$ max increasing 8% for the high activity group and approximately 15% for the low activity group. It is difficult to equate the perceptions of effort (RPE) reported because of the different workloads involved at the end of the training program. The other measures of aerobic fitness, ventilation ($V_E$ max), maximum heart rate ($HR_{max}$) and maximum workload (speed/grade) also showed the anticipated improvement as a result of training.

Table 3 describes the physiological and perceptual responses to a 20 minute endurance run at 70% of $\dot{V}O_2$ max. While the first two endurance runs were based on initial $\dot{V}O_2$ max values, the post-training 70% workload was calculated based on the subjects post-training $\dot{V}O_2$ max; i.e. absolute workload was increased from 8-15% for the groups. It can be seen that the perceptual responses to the same workload (pre-acute) were quite different. This finding suggests that exposure and activity experience alone may play an important role in understanding work performance in women even if no training is involved.

Data analysis of these physiological and perceptual measures across replications of the maximal performance and endurance tests are in progress. It can be seen in Table 4 that psychological measures of attitude toward activity, physical self-estimation, hidden shapes, motor satisfaction, perceived control of the environment (lack of control) and physical self concept did not demonstrate

substantial differences between the high and low activity groups. However, it is noteworthy that many of these measures were apparently different from the college norm population scores. This could be expected in light of the activity experience of the latter group.

In general the preliminary data analysis indicates that perceptual responses are intricately involved in the development of physical work capacity in women. Comparison of differences in peripheral responses between women and men will be reported subsequently. The population studied appears to be rather unique and superior to the college norms making psychological comparisons difficult; however, additional analysis is in progress.

Presentations:

None

Publications:

None

LITERATURE CITED


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2. Pollack, M. In: Exercise and Sports Sciences Review, J. H. Wilmore (ed) N.Y., Academic Press, 1970.

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TABLE I. Anthropometric Characteristics of Women with Different Activity Patterns Before and After an Endurance Training Program.

| | | Experience | | | | |
|---|---|---|---|---|---|---|
| | | Low Activity | | | High Activity | |
| | | Pre -Training | Post-Training | | Pre -Training | Post-Training |
| Height (cm) | E | 166.7 ± 1.4 | 166.8 ± 1.4 | E | 166.1 ± 1.3 | 166.2 ± 1.3 |
| | C | 162.9 ± 2.4 | 163.4 ± 2.6 | C | 166.1 ± 2.0 | 165.9 ± 2.1 |
| Weight (Kg) | E | 60.9 ± 1.6 | 61.4 ± 1.6 | E | 57.8 ± 1.6 | 58.9 ± 1.5 |
| | C | 57.7 ± 2.2 | 57.6 ± 2.2 | C | 59.2 ± 1.7 | 60.2 ± 2.1 |
| Body Fat (%) | E | 18.8 ± 0.9 | 18.3 ± 0.9 | E | 14.9 ± 1.0 | 14.7 ± 1.2 |
| | C | 16.1 ± 1.1 | 16.0 ± 1.1 | C | 16.5 ± 0.6 | 17.2 ± 0.9 |

Values represent means ± S.E. E = experimental (aerobic training)
C = control (non-training)

TABLE 2. Physiological and Perceptual Responses to Acute and Chronic Exposure to Maximal Treadmill Performance

| | | Experience | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Low Activity | | | | High Activity | | |
| | | Pre | Acute | Post Training | | Pre | Acute | Post Training |
| $\dot{V}O_2$ max (L/min) | E | 2.38 ± .07 | 2.38 ± .07 | 2.72 ± .07 | E | 2.48 ± .09 | 2.51 ± .07 | 2.77 ± .08 |
| | C | 2.43 ± .09 | | 2.55 ± .09 | C | 2.58 ± .08 | | 2.73 ± .11 |
| $\dot{V}O_2$ max (ml/kg | E | 36.9 ± .08 | 37.9 ± .4 | 42.3 ± 1.1 | E | 43.9 ± 1.2 | 44.2 ± 1.0 | 47.8 ± 1.1 |
| per min) | C | 38.8 ± 1.2 | | 40.6 ± 1.1 | C | 45.6 ± 1.1 | | 46.6 ± 0.9 |
| Max HR | E | 194 ± 1 | 192 ± 1 | 187 ± 2 | E | 189 ± 1 | 187 ± 2 | 187 ± 2 |
| | C | 193 ± 2 | | 193 ± 2 | C | 191 ± 2 | | 190 ± 2 |
| Max $V_E$ | E | 91.6 ± 3.5 | 91.5 ± 4.1 | 96.6 ± 4.3 | E | 91.5 ± 4.0 | 95.9 ± 3.5 | 102.7 ± 3.4 |
| | C | 90.1 ± 3.7 | | 102.6 ± 3.0 | C | 89.5 ± 4.8 | | 99.1 ± 5.9 |
| RPE max | E | 17.2 ± .3 | 15.7 ± 0.6 | 17.9 ± 0.4 | E | 17.6 ± .4 | 17.5 ± 0.4 | 18.2 ± 0.4 |
| | C | 16.9 ± .7 | | 17.7 ± 0.7 | C | 17.2 ± .4 | | 16.8 ± 0.5 |
| Max work load | E | 5.3/6.1 | 5.4/7.7 | 6.4/9.9 | | 6.0/7.0 | 5.7/8.6 | 6.5/9.7 |
| | C | 5.4/6.1 | | 5.7/7.6 | | 5.7/7.5 | | 6.0/8.8 |

Values are mean ± S.E. E = experimental (aerobic training)
C = control (non-training)

TABLE 3. Physiological and Perceptual Responses to a 20 Minute Endurance Run at 70% Max during the Last Minute of Performance

| | | Experience | | | | | |
|---|---|---|---|---|---|---|---|
| | | Low Activity | | | High Activity | | |
| | | Pre | Acute | Post | Pre | Acute | Post-Training |
| State Anxiety | E | 5.9 ± 0.5 | 5.3 ± 0.4 | 4.8 ± 0.1 | 5.8 ± 0.5 | 5.3 ± 0.4 | 5.1 ± 0.2 |
| | C | 5.8 ± 0.8 | | 4.7 ± 0.1 | 5.1 ± 0.4 | | 5.0 ± 0.1 |
| RPE | E | 12.6 ± 0.6 | 11.3 ± 0.6 | 10.9 ± 6.7 | 11.7 ± 0.4 | 11.1 ± 0.4 | 10.8 ± 0.4 |
| | C | 13.3 ± 0.8 | | 12.8 ± 6 | 11.5 ± 0.7 | | 11.0 ± 0.6 |
| Heart Rate | E | 172 ± 4 | 162 ± 4 | 171 ± 4 | 163 ± 4 | 154 ± 3 | 161 ± 4 |
| | C | 176 ± 5 | | 182 ± 3 | 167 ± 3 | | 174 ± 5 |

Values represent means ± S.E.

E = experimental (aerobic training)
C = control (non-training)

TABLE 4. Performance Expectations and Self Evaluation of Physical Abilities in Women of Different Activity Patterns Before and After an Endurance Training Program

| Variable | N | | Low Activity Pre | Low Activity Post-Training | N | | High Activity Pre | High Activity Post-Training | College* Norms |
|---|---|---|---|---|---|---|---|---|---|
| Attitude Toward Physical Activity | 22 | E | 31.75 ± 6.4 | 33.36 ± 6.7 | 18 | E | 38.78 ± 4.5 | 36.11 ± 11.0 | 32.5 |
| | 10 | C | 31.90 ± 7.9 | 34.5 ± 10.2 | 10 | C | 36.85 ± 4.3 | 37.29 ± 12.4 | |
| Physical Self-Estimation | 22 | E | 17.70 ± 5.5 | 19.13 ± 6.0 | 18 | E | 22.33 ± 5.9 | 23.78 ± 7.8 | 18.7 |
| | 10 | C | 19.10 ± 6.9 | 19.18 ± 8.4 | 10 | C | 21.64 ± 5.4 | 23.57 ± 8.5 | |
| Hidden Shapes | 22 | E | 32.5 ± 4.5 | 33.41 ± 2.6 | 18 | E | 32.16 ± 4.7 | 34.22 ± 2.6 | 15.37 |
| | 10 | C | 30.6 ± 6.8 | 35.1 ± 1.4 | 10 | C | 32.35 ± 3.4 | 32.7 ± 4.7 | |
| Motor Satisfaction Scale | 22 | E | 163.3 ± 25.7 | 175.8 ± 28.3 | 18 | E | 167.8 ± 31.1 | 195.9 ± 27.8 | 143 |
| | 10 | C | 163.0 ± 24.1 | 171.8 ± 30.9 | 10 | C | 162.1 ± 36.6 | 184.4 ± 32.1 | |
| Locus of Control I-E | 22 | E | 9.8 ± 4.1 | 9.7 ± 3.9 | 18 | E | 9.24 ± 4.1 | 8.05 ± 4.4 | 9.62 |
| | 10 | C | 10.5 ± 3.3 | 10.3 ± 4.7 | 10 | C | 8.5 ± 2.4 | 10.0 ± 3.7 | |
| Physical Self Concept | 22 | E | 62.7 ± 9.2 | 63.4 ± 9.4 | 18 | E | 69.22 ± 7.3 | 71.8 ± 7.2 | |
| | 10 | C | 64.0 ± 10.2 | 61.4 ± 10.8 | 10 | C | 67.14 ± 7.9 | 70.2 ± 10.7 | |

Values Represent (Means ± S.D.)

E = experimental (aerobic training)

C = control (non-training)

*Represent combined male and female values

(83051)

| RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY | 1. AGENCY ACCESSION* | 2. DATE OF SUMMARY* | REPORT CONTROL SYMBOL |
|---|---|---|---|
| | DA OA 6148 | 77 10 01 | DD-DR&E(AR)636 |

| 3. DATE PREV SUM'RY | 4. KIND OF SUMMARY | 5. SUMMARY SCTY* | 6. WORK SECURITY* | 7. REGRADING* | 8a. DISB'N INSTR'N | 8b. SPECIFIC DATA-CONTRACTOR ACCESS | 9. LEVEL OF SUM |
|---|---|---|---|---|---|---|---|
| 77 09 02 | D. Change | U | U | N/A | N/L | XX YES ☐ NO | A. WORK UNIT |

| 10. NO./CODES:* | PROGRAM ELEMENT | PROJECT NUMBER | TASK AREA NUMBER | WORK UNIT NUMBER |
|---|---|---|---|---|
| a. PRIMARY | 6.27.77.A | 3E762777A845 | 00 | 051 |
| b. CONTRIBUTING | | | | |
| XXXXXXXXX | CARDS 114f | | | |

11. TITLE (Precede with Security Classification Code)* (U) Prevention and Treatment of Disabilities Associated with Military Operations at High Terrestrial Elevations (22)

12. SCIENTIFIC AND TECHNOLOGICAL AREAS*

012600 Pharmacology; 005900 Environmental Biology; 013400 Physiology

| 13. START DATE | 14. ESTIMATED COMPLETION DATE | 15. FUNDING AGENCY | 16. PERFORMANCE METHOD |
|---|---|---|---|
| 70 07 | CONT | DA | In-House |

17. CONTRACT/GRANT

a. DATES/EFFECTIVE: EXPIRATION:
b. NUMBER:* NOT APPLICABLE
c. TYPE: d. AMOUNT:
e. KIND OF AWARD: f. CUM. AMT.

| 18. RESOURCES ESTIMATE | | a. PROFESSIONAL MAN YRS | b. FUNDS (In thousands) |
|---|---|---|---|
| FISCAL YEAR | PRECEDING 77 | 9.5 | 205.7 |
| | CURRENT 78 | 9.0 | 300.7 |

19. RESPONSIBLE DOD ORGANIZATION

NAME:* USA RSCH INST OF ENV MED

ADDRESS:* Natick, MA 01760

RESPONSIBLE INDIVIDUAL

NAME: DANGERFIELD, HARRY G., M.D., COL, MC

TELEPHONE: 955-2811

20. PERFORMING ORGANIZATION

NAME:* USA RSCH INST OF ENV MED

ADDRESS:* Natick, MA 01760

PRINCIPAL INVESTIGATOR (Furnish SSAN if U.S. Academic Institution)

NAME:* MAHER, John T., Ph.D.

TELEPHONE: 955-2851

SOCIAL SECURITY ACCOUNT NUMBER:

ASSOCIATE INVESTIGATORS

NAME: KOBRICK, John L., Ph.D.

NAME: 955-2885 DA

21. GENERAL USE

Foreign Intelligence Not Considered

22. KEYWORDS (Precede EACH with Security Classification Code) (U)Acute Mountain Sickness; (U)High Altitude Pulmonary Edema; (U)Visual Search Performance; (U)Ventilatory Muscle Training

23. TECHNICAL OBJECTIVE,* 24. APPROACH, 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)

23. (U) Exposure of soldiers to high terrestrial elevations results frequently in reduced military performance as well as medical disabilities which are incompatible with the successful completion of military operations. The purpose of this work unit is to investigate methods of prevention and treatment of these performance decrements and disabilities.

24. (U) Studies will be conducted in animals and man to (1) determine the mechanisms of the physiologic alterations and medical disabilities at altitude; (2) assess and predict the performance of individuals and small units operating at altitude; (3) evaluate the efficacy of pharmacological agents and other means in preventing or reducing performance decrements and illness; (4) enhance the rate of adaptation to high terrestrial elevations.

25. (U) 76 10 - 77 09 (1) Lung function measurements revealed that subclinical pulmonary edema and/or pulmonary vascular congestion commonly occur in soldiers performing strenuous exercise at high altitude; (2) Data collected on visual search patterns have indicated that during early hypoxia the frequency of observations was reduced, followed by gradual recovery. The size of the visual search area was unaffected; (3) Training of the muscles of respiration for an hour each weekday for 6 weeks resulted in a 28 percent increase in the maximum voluntary ventilation which 6 normal men could sustain at a preset level for 15 minutes; (4) Studies have been carried out which assessed the influence of physical fitness on performance at high altitude as reflected by measurements of symptomatology, work capacity, pulmonary function and visual perception.

*Available to contractors upon originator's approval

| | |
|---|---|
| Program Element: | 6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE |
| Project: | 3E762777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance |
| Work Unit: | 051 Prevention and Treatment of Disabilities Associated with Military Operations at High Terrestrial Elevations |
| Study Title: | Ventilatory Muscle Training and Ventilatory Control during Loaded Breathing |
| Investigators: | Ronald A. Gabel, M.D., David E. Leith, M.D., Beverly Philip, M.D. and Vladimir Fencl, M.D. |

Background:

The effectiveness of a military operation may be limited by inability of the troops to function in a hostile environment. Such limiting environments would be found at high terrestrial altitudes and in the presence of incapacitating chemical or biological agents. In these settings, the requirement often exists for the soldier to wear protective devices which add resistive loads at the airway.

Human exercise capacity is decreased when the resistance to breathing is increased, for example by oxygen or gas masks or by dense gases (1,2). The early cessation of exercise under these circumstances is associated with relatively low ventilation and high $CO_2$ levels. It has not been understood whether or how much this should be attributed to fatigue of the breathing muscles due to increased work of breathing, or to behavior of the respiratory control system under conditions of heavy exercise and loaded breathing.

Endurance of the ventilatory muscles can be increased by suitable training (3). If exercise performance is limited by fatigue of the breathing muscles, ventilatory muscle training might have the potential to improve whole-body exercise performance during loaded breathing. Little is known, however, about changes which might be induced in the ventilatory control system by substantial alterations in the ventilatory effector system. If behavior of the respiratory control center is not fundamentally changed by ventilatory muscle training, neural efferent activity for a given level of afferent activity might be the same before and after

ventilatory muscle training, resulting in a greater ventilatory response to a given physiologic stimulus after training. Alternatively, because of substantial feedback of proprioceptive information regarding adequacy of ventilation, neural efferent traffic from the respiratory centers may be decreased after ventilatory muscle training, such that the ventilatory response to a given physiologic stimulus after training is equal to or less than that before training.

Progress:

Thirteen healthy young male volunteer subjects were studied twice. Between the two sets of tests, eight "trainers" underwent six weeks of ventilatory muscle training, while five "controls" spent a six-week period involving no training activities. Pre- and post-training measurements included lung volumes by spirometry, maximum expiratory flow-volume curves, and 15-second maximum voluntary ventilation (MVV). Also included were determinations of ventilatory muscle capacities of two kinds: 1) "Strength" was measured by occluding a mouthpiece at 20-percent intervals over the vital capacity range and having the subject exert maximum inspiratory or expiratory efforts while measuring mouth pressure. 2) "Endurance" was measured by having the subject voluntarily breathe at about 70 to 95 percent of his MVV through an apparatus designed to give him a ventilatory target and to provide partial rebreathing to prevent hypocapnia. In addition to the above, before and after training (or, for controls, a 6-week training-free period) ventilation of each subject was measured during quasi steady-state conditions at end-tidal carbon dioxide tensions of approximately 45, 50, and 55 torr. Ventilation at each level of carbon dioxide was measured with the inspiratory passage unobstructed and with two levels of inspiratory resistance added to the apparatus. All measurements were performed at least once on each of three different days.

For up to an hour each weekday for six weeks, the "trainers" tried to match a ventilatory target set at between 40 and 85 percent of their MVV. They either matched the target for 15 minutes or stopped voluntarily when they could no longer continue because of fatigue. A flow resistance was included in the inspiratory limb of the training apparatus so that mouth pressures of -70 to -90 $cmH_2O$ were

required to achieve ventilations of 80-120 L/min, a severe load. The apparatus provided for partial rebreathing to maintain end-tidal carbon dioxide tensions near normal.

Data collection is complete, but compilation and analysis have only just started. Thus far, it appears that ventilatory training using added inspiratory flow resistance, a new method, is at least as capable of producing an increase in ventilatory endurance as the method previously described (3). The MVV of trainers increased an average of 11.2 L/min, or 6.1 percent, during training, while the MVV of controls decreased an average of 4 L/min, or 2 percent, during a 6-week period of non-training (Table 1). Neither the increase in MVV of the trainers ($P = 0.085$) nor the decrease in MVV of the controls ($P = 0.468$) was statistically significant.

"Sustained ventilatory capacity" (SVC) was increased by the ventilatory endurance training. This variable was defined as the maximum voluntary ventilation which could be sustained at a preset level for 15 minutes. The SVC of the trainers increased 36 L/min, or 27.6 percent, during training ($P = 0.0005$), while the SVC of controls did not increase significantly during a 6-week period of non-training ($P = 0.336$)(Table 2).

In some subjects the training of ventilatory muscles seems to have led to a substantial reduction in the ventilatory response to carbon dioxide. Although preliminary, these unexpected results appear to confirm our suspicion that ventilatory muscle training may lead to important changes in the way humans alter their breathing in response to physiologic stimuli.

**Presentations:**

None

**Publications:**

None

Table 1. Fifteen-Second Maximum Voluntary Ventilation (MVV) Before and After 6 Weeks of Ventilatory Endurance Training (Trainers) or a 6-Week Training-Free Period (Controls)

| | MVV (L/min) | | | |
|---|---|---|---|---|
| | BEFORE | AFTER | CHANGE | PERCENT CHANGE |
| TRAINERS | | | | |
| GD | 129 | 136 | +7 | +5.4 |
| RS | 163 | 174 | +11 | +6.7 |
| RT | 153 | 148 | +5 | +3.3 |
| GH | 163 | 179 | +16 | +9.8 |
| RK | 192 | 194 | +2 | +1.0 |
| RC | 249 | 275 | +26 | +10.4 |
| | | MEAN | +11.2 | +6.1 |
| CONTROLS | | | | |
| VF | 215 | 217 | +2 | +0.9 |
| VL | 167 | 179 | +12 | +7.2 |
| MC | 173 | 167 | -6 | -3.5 |
| AV | 198 | 185 | -13 | -6.6 |
| RP | 172 | 157 | -15 | -8.7 |
| | | MEAN | -4.0 | -2.1 |

Table 2. Sustained Ventilatory Capacity (SVC) (Defined in Text) Before and After 6 Weeks of Ventilatory Endurance Training (Trainers) or a 6-Week Training-Free Period (Controls)

| | SVC (L/Min) | | | |
|---|---|---|---|---|
| | BEFORE | AFTER | CHANGE | PERCENT CHANGE |
| TRAINERS | | | | |
| GD | 110 | 144 | +34 | +30.9 |
| RS | 144 | 188 | +44 | +30.6 |
| RT | 109 | 161 | +52 | +47.7 |
| GH | 120 | 141 | +21 | +17.5 |
| RK | 156 | 184 | +28 | +17.9 |
| RC | 178 | 215 | +37 | +20.8 |
| | | MEAN | +36.0 | +27.6 |
| CONTROLS | | | | |
| VF | 146 | 144 | -2 | -1.4 |
| VL | 149 | 141 | -8 | -5.4 |
| MC | 146 | 155 | +9 | +6.2 |
| AV | 130 | 147 | +17 | +13.1 |
| RP | 142 | 150 | +8 | +5.6 |
| | | MEAN | +4.8 | +3.6 |

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3. Leith, D. E., and M. Bradley. Ventilatory muscle strength and endurance training. J. Appl. Physiol. 41:508-516, 1976.

Program Element: 6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE

Project: 3E762777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance

Work Unit: 051 Prevention and Treatment of Disabilities Associated with Military Operations at High Terrestrial Elevations

Study Title: Effects of Hypoxia on Characteristic Patterns of Scanning the Visual Field

Investigators: John L. Kobrick, Ph.D. and James A. Devine

Background:

A recent concept in research on visual perception is that the visual field is organized into central and peripheral components (1,2,3) and that the two separate sub-systems are functionally connected by the action of eye movements. This concept is directly related to visual search, a type of performance involved in many military activities such as surveillance, sentry scanning, target detection, and others. Better understanding of this system would be of real benefit in explaining the influence of environmental stress, such as hypoxia, on the visual system as it relates to military performance. There is some evidence to indicate that hypoxia reduces the functional visual field (4,5). It has also been shown that hypoxia exposure directly reduces the functional efficiency of the peripheral visual field for effective target detection (6,7,8).

One methodological difficulty in detailed analysis of visual search performance is that of determining where the subject is looking from moment to moment, what he sees, and whether this information is functionally recognized. Such analysis by studying eye movements has always been hampered by difficulties of interpretation of specific components of the performance from the overall measurements obtained.

Progress:

The present task was developed to provide a simplified methodology for determining and analyzing the progressive development of patterns of search, and was felt to have potential utility in analyzing the effects of hypoxia exposure on such types of visual perception, and for helping to determine the relative roles of the central and peripheral visual systems. The subject was seated in front of a projection screen so that it filled the majority of his visual field. The apparatus consisted essentially of a slide projector with tachistoscopic shutter which briefly exposed a matrix of numbers on the screen (1/2 sec. exposure every 10 seconds). The number matrix consisted of 100 2-digit numbers (00 through 99) arranged in a 10 x 10 array, but random as numbers. The subject merely reported what he saw each time the same repeating matrix appeared. Since the positions of the numbers were known, it was possible to determine and analyze any patterns of visual search which may have developed as the subject successively viewed and gained experience with the same scene.

The subjects were 24 soldier volunteers drawn from the 10th Special Forces Group, Fort Devens, MA. All subjects were trained and tested in the same manner. They received an initial training and orientation session at a sea level location. They were told to report only what they saw each time the matrix appeared, in order to avoid leading them into atypical search patterns which might not represent their customary visual search behavior. They were then tested at sea level to provide a baseline for comparing later performance, whereupon they were transported to a moderately high elevation site in the White Mountains, NH (300-1040 meters) for a 3-day military maneuver. During this period, they were tested periodically three times on the visual search task, and were then transported to a high altitude site at Pike National Forest, CO (3600-4300 meters) where they participated in another 3-day tactical maneuver. During this period, they were tested periodically three more times on the present task. Each session consisted of 10 minutes of repeated exposures of the number matrix. Different but equivalent matrices were used for each testing session, the entire subject group receiving the same matrix in each testing.

The data obtained have been analyzed so far through conversion to two indices: (1) the equivalent radial distance of each target (matrix number reported from the center of the matrix, the customary natural fixation point in normal viewing; (2) the total number of targets (matrix numbers) reported in each testing session. The former was considered to be an estimate of the degree of central or peripheral search performed, and the latter was expected to give an indication of the level of search activity shown by the subjects. The group arithmetic means of targets reported in each testing session are shown in Table 1, as well as Student's paired t values for significance of the differences between sea level and second testing at altitude, second and fourth altitude sessions, and fourth and sixth altitude sessions.

TABLE 1. GROUP MEANS OF TARGETS REPORTED PER SESSION & SIGNIFICANCE OF DIFFERENCES BETWEEN SESSION VALUES

| SESSION | GROUP MEAN TARGETS | STUDENTS t | P |
|---|---|---|---|
| SEA LEVEL | 161 | | |
| LOW ALTITUDE 1 | 175 | 4.91 | .001 |
| LOW ALTITUDE 2 | 181 | | |
| LOW ALTITUDE 3 | 174 | 1.09 | .10 |
| HIGH ALTITUDE 1 | 169 | | |
| HIGH ALTITUDE 2 | 178 | 2.97 | .001 |
| HIGH ALTITUDE 3 | 194 | | |

It can be seen that a large improvement in performance occurred, indicating that in future use of this task, the subjects should receive considerable practice prior to experimental test under environmental conditions. However, there is a sharp reduction in targets reported from the second to fourth altitude sessions, corresponding to the second testing at moderate altitude and the first testing at high altitude. This can be most likely attributed to the combined effects of altitude exposure and fatigue produced by the heavy exercise involved in the tactical maneuvers. The impairment trend appears to have been replaced thereafter by continued improvement throughout the remainder of high altitude

exposure. These results are consistent with previous findings in the literature cited above, in which perceptual and cognitive behavior is very quickly affected by altitude exposure, showing the greatest decrement during the first few hours. This is typically followed by gradual recovery of performance. Such performance is in contrast to the usual pattern of development of acute mountain sickness, which only becomes manifest after considerable time at altitude. Once again must be noted that the tactical soldier appears to be least cognitively proficient in the first few hours at altitude, when he may be expected to be operational in sudden attacks and airdrop operations. His performance in this respect cannot be predicted from his medical condition at the time. The group arithmetic means are shown graphically in Figure 1.

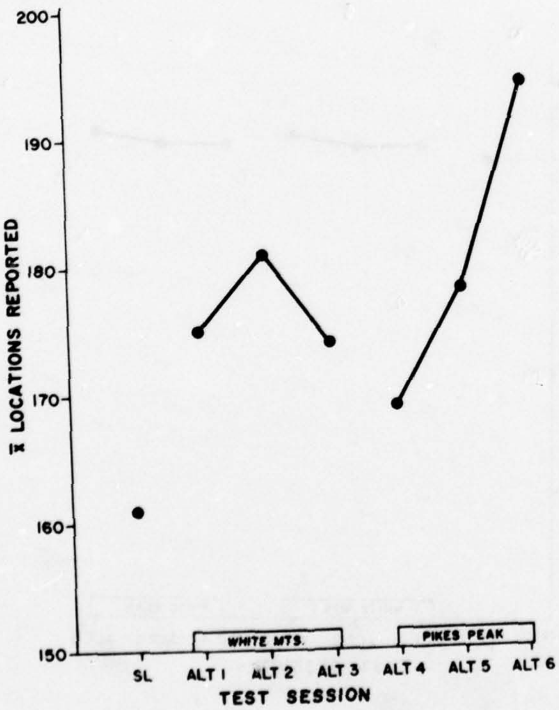


Figure 1. Group mean of targets reported at low and high elevation exposures.

The group arithmetic means of radial distance from center of targets reported are presented in Table 2, and are shown graphically in Figure 2.

TABLE 2. GROUP MEAN RADIAL DISTANCE FROM CENTER OF TARGETS REPORTED

| SESSION | GROUP MEAN RADIAL DISTANCE |
|---|---|
| SEA LEVEL | 3.59 |
| LOW ALTITUDE 1 | 3.70 |
| LOW ALTITUDE 2 | 3.69 |
| LOW ALTITUDE 3 | 3.79 |
| HIGH ALTITUDE 1 | 3.71 |
| HIGH ALTITUDE 2 | 3.71 |
| HIGH ALTITUDE 3 | 3.78 |

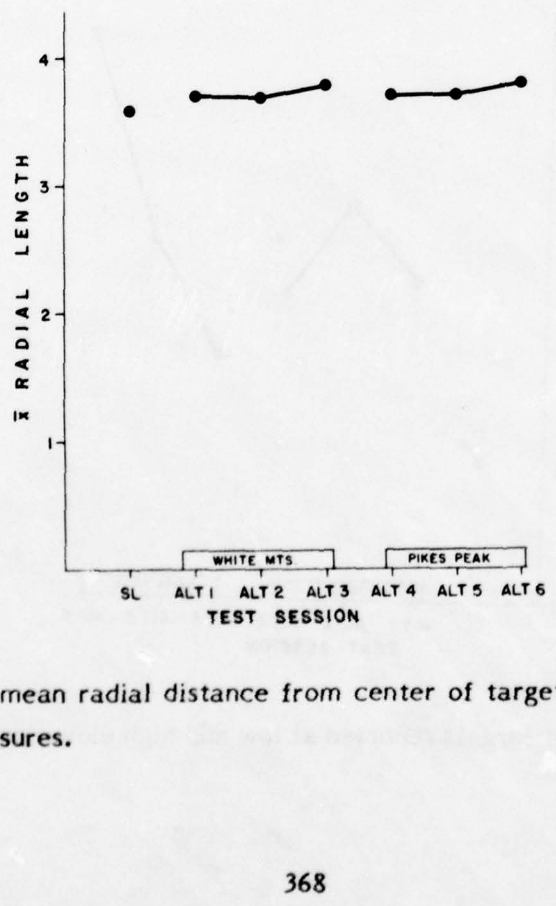


Figure 2. Group mean radial distance from center of targets reported at low and high altitude exposures.

It is clear that performance in this respect differed very little from session to session. T-tests as described above performed on these values were nonsignificant. It would seem that although the scanning activity level of the subjects was influenced by hypoxia, the area size scanned by them was not. It may be that the period of exposure during which the subjects could see the matrix was too short to allow more peripheral behavior. The effects of hypoxia on this task performance should be studied further using longer exposure periods to determine whether peripheral viewing may still occur. The task appears to be potentially useful in measuring visual search under hypoxia. The reduced activity observed is typical of perceptual performance under such exposure, in which the subject customarily becomes sleepy, inattentive, and unmotivated. Such tendencies have been reflected here in actual reduced productive work, which does not seem to have been due to boredom, since the performance curve increased once the earlier effects of hypoxia abated. Further analysis is in progress to relate personality measures also obtained on the subjects to their characteristic search patterns, which on visual inspection are noticeably different from each other.

Presentations:

None.

Publications:

None.

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| | |
|---|---|
| Program Element: | 6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE |
| Project: | 3E762777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance |
| Work Unit: | 051 Prevention and Treatment of Disabilities Associated with Military Operations at High Terrestrial Elevations |
| Study Title: | Effect of 3 Days of Outdoor Physical Activity at High Altitude on Thoracic Impedance and Alveolar-Arterial Oxygen Gradients |
| Investigators: | Allen Cymerman, Ph.D., John T. Maher, Ph.D., Joseph C. Denniston, MAJ, VC, Jimmie T. Sylvester, MAJ, MC, James J. Jaeger, CPT, MSC and Joel J. Berberich, CPT, MSC |

Background:

High altitude pulmonary edema (HAPE) is one of the most serious medical problems associated with exposures to high altitude. It is of special concern to military planners since it poses a life-threatening situation, the probability of which increases when physical exertion is also involved (1). The relatively low incidence of HAPE that has been reported may be attributed to the fact that the symptoms are often associated with less severe maladies and that medical treatment and return to sea level alleviates the condition.

It is our hypothesis that the pathophysiological processes that occur with altitude-induced pulmonary edema are present in all exposed individuals, but these processes are usually self-limiting and regress to the extent that clinical pulmonary edema is infrequently observed. To test this hypothesis, we investigated the nature, incidence, and severity of subclinical pulmonary edema in unacclimatized soldiers abruptly committed to a combat military training exercise at high altitude. Two measurements were used to detect subclinical pulmonary edema: the alveolar-arterial oxygen gradient and the transthoracic impedance level. The alveolar-arterial oxygen gradient, $(A-a)DO_2$, exists because the lung is not a perfect gas exchanger. The gradient is caused by anatomical shunts, by unequal distribution of ventilation to perfusion ratios and by the diffusion barrier created by the alveolar membrane. Pulmonary edema would have a detrimental effect on this gradient by

possibly altering the latter two causal factors. Thus, subclinical pulmonary edema would reduce the efficiency of the lung to transport oxygen from the alveoli to the pulmonary capillaries. This situation would be reflected by an increase in the $(A-a)DO_2$ gradient.

Thoracic impedance has been used clinically to evaluate pulmonary edema and thoracic lung volumes (2). The theoretical rationale rests on the fact that changes in fluid volume within the body segment being measured will produce changes in the distribution of an applied high frequency current which is measured at the body surface as a change in potential. Because the applied current is constant, changes in potential represent changes in impedance which are related to fluid volume because of the constancy of the ionic composition of intra- and extracellular fluid. Thus, it is expected that a reduction in impedance would represent an increase in thoracic fluid, while an increase would reflect a decreased thoracic fluid volume.

## Progress:

Initial testing was performed during a 72-hour, 84 km hike in the White Mountain National Forest (NH) (200-875 meters elevation). One week later the subjects were transported to Pike National Forest (CO) (3000-4300 meters elevation) where they were tested again during a 72-hour, 30 km hike. Impedance measurements were conducted at 0, 36, and 72 hours of each field maneuver. Blood samples were obtained only at 0 and 72 hours at each location.

Arterial blood samples were obtained from the radial artery of 25 resting, supine subjects. The samples were immediately analyzed for pH, $CO_2$ and $O_2$ partial pressures. Expired air from resting, supine subjects was collected in Douglas bags and immediately analyzed for percent $O_2$ and $CO_2$. Data on frequency and depth of respiration were also collected. The results were then used to calculate alveolar oxygen partial pressure ($P_{A_{O_2}}$) and, in conjunction with the arterial oxygen partial pressure ($P_{a_{O_2}}$), the $(A-a)DO_2$ gradient.

Transthoracic impedance was measured with an impedance cardiograph and aluminized Mylar tape electrodes placed at four standardized positions on the neck and thorax. Measurements were made after a 5-minute supine rest period at end expiration and again standing at total lung capacity to compensate for any changes due to shifts in functional residual capacity.

The (A-a)$DO_2$ gradient did not change significantly with exposure to altitude; however, a significant reduction was observed across time. That is, under conditions of both low and high altitude there was a reduction in the gradient after 72 hours (Figure 1). This result may have been associated with the continued exercise but this would have to be verified by taking more measurements across time. The lack of any change after 19 hours to 7-10 days in the (A-a)$DO_2$ gradient has been reported previously (3,4). However, Reeves et al. (5) found an increase after only 3 hours exposure to a simulated altitude of 4572 meters. This may be accounted for by the fact that the latter investigators were able to test each subject at a specified exposure time, while our study necessitated testing subjects over a period of 6 hours, thus possibly obviating any changes.

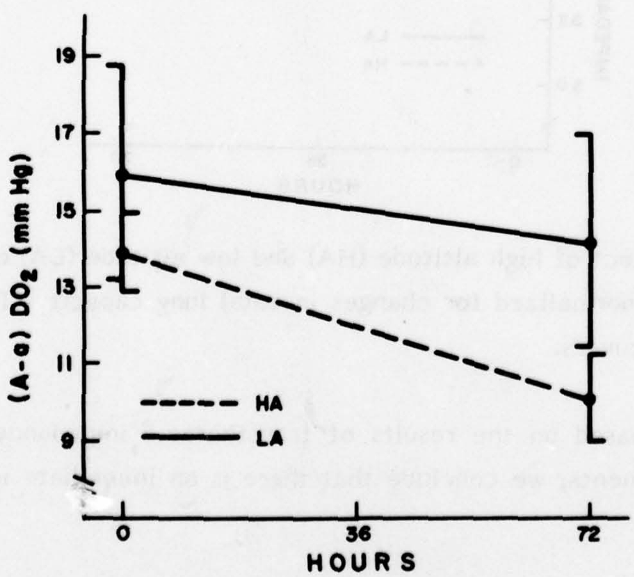


Figure 1. The effect of high altitude (HA) and low altitude (LA) on the alveolar oxygen gradient, (A-a)$DO_2$, during two 72-hour field maneuvers.

Figure 2 depicts changes in transthoracic impedance measured at total lung capacity over the course of 72 hours at low and high altitude. Impedance values were normalized by correcting for any possible changes in total lung capacity. The mean impedance values were significantly lower at the onset of high altitude exposure (3.62 versus 3.98 ohms) and after 36 hours (3.54 versus 3.87 ohms). There were no significant differences after 72 hours. The decrease in transthoracic impedance levels with acute exposure to altitude suggests an increase in fluid volume within the chest. This result agrees with Indian investigators who studied 30 subjects and found a significant reduction within 4 days exposure to 3658 meters altitude (6).

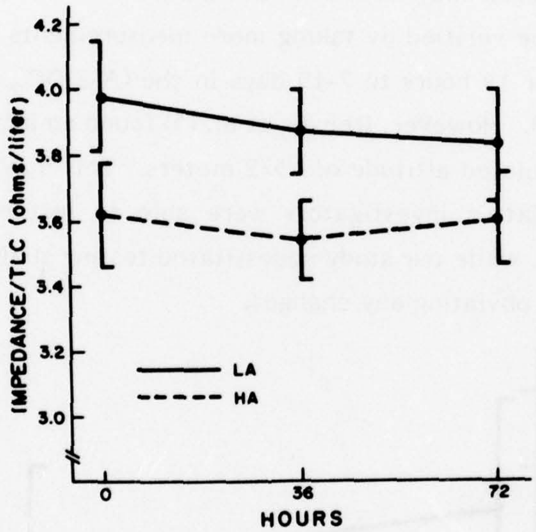


Figure 2. The effect of high altitude (HA) and low altitude (LA) on transthoracic impedance levels normalized for changes in total lung capacity (TLC) during two 72-hour field maneuvers.

Therefore, based on the results of transthoracic impedance and (A-a)$DO_2$ gradient measurements, we conclude that there is an immediate increase in fluid

within the chest with abrupt ascent to altitude which persists up to 72 hours. The location of this increase in fluid cannot be determined. The lack of deterioration of the $(A\text{-}a)DO_2$ gradient suggests that the fluid increase may be intravascular rather than extravascular since gas exchange was not compromised.

Presentations:

Cymerman, A., J. T. Maher, J. C. Denniston, J. T. Sylvester, J. J. Jaeger and J. J. Berberich. Effect of 3 days of outdoor physical activity at high altitude on thoracic impedance and alveolar-arterial oxygen gradients. Presented, Annual Meeting, FASEB, Chicago, IL, 1-8 April 1977 (Fed. Proc. 36:533, 1977).

Publications:

None.

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Program Element: 6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE

Project: 3E762777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance

Work Unit: 051 Prevention and Treatment of Disabilities Associated with Military Operations at High Terrestrial Elevations

Study Title: The Effects of Physical Fitness on Performance at High Altitude

Investigators: Allen Cymerman, Ph.D., James J. Jaeger, CPT, MSC, John T. Maher, Ph.D., John L. Kobrick, Ph.D., Gerald L. Davis, Ph.D. and Ronald Williams, LTC, MC

Background:

The abrupt exposure of man to terrestrial elevations in excess of 3000 meters may be accompanied by symptoms of acute mountain sickness (AMS) and/or high altitude pulmonary edema (HAPE). The use of troops at or above this altitude necessitates optimal physical and mental performance in a hypoxic environment. The present study is an attempt to determine whether the level of physical fitness of subjects exposed to high altitude has any effect on AMS and HAPE symptoms, physical performance, pulmonary function, visual perception, and hemostasis.

The variability of AMS in susceptibility and severity of symptoms has been noted by many investigators. Such factors as rate and degree of ascent, diet, physical exertion, and level of physical fitness may all play a role in the severity of symptoms. The statement has been made that the level of physical fitness may confer some benefit with regard to severity of AMS and that physical conditioning should be a possible measure to ameliorate AMS (1,2). This assumption has not been confirmed. Hansen et al. (3) reported that cardiovascular fitness did not protect against AMS since the correlation between symptom severity and oxygen consumption was not significant. This study, however, lacked well-defined groups of "fit" and "unfit" individuals and, therefore, was not a good test of the hypothesis.

Maximum aerobic power ($\dot{V}O_2$ max), a measure of cardiovascular fitness, is

decreased as the inspired oxygen tension is reduced from sea level to high altitude. Several studies have indicated that in well-conditioned young men $\dot{V}O_2$ max decreased less per thousand feet elevation than in all subjects combined (4). This is in marked contrast to studies discussed by Grover (5) in which he states "that men of high working capacity suffer a greater decrement in $\dot{V}O_2$ max at altitude than do men of only moderate working capacity." This study investigated the altitude-related reduction in two groups of subjects which varied widely in $\dot{V}O_2$ max.

A previous study by USARIEM investigators (see annual report entitled, "Changes in Closing Capacity and Lung Volumes During 3 Days of Physical Activity at High Altitude") indicated that significant changes occurred within 3 days in vital capacity, residual volume, closing capacity and the pulmonary compliance curve. These changes may be suggestive of the development of interstitial pulmonary edema. In order to confirm these acute changes and to determine whether they persist with longer exposures, vital capacity and closing capacity were measured. In addition, the design of the present study allowed measurements to be made both before and after exercise. Measurements immediately after exercise should magnify any changes in pulmonary function.

One of the theories explaining the etiology of AMS and HAPE involves the possibility of capillary occlusion by red cells, platelet aggregates, or microthrombi. Occlusion of several capillaries subjects patent capillaries to increased perfusion pressures and possible edema formation. In a recent study, we showed alterations in fibrinogen and factor VIII (antihemophilic factor) levels with normal platelet function in subjects acutely exposed to 4400 meters (6). Gray et al. (7) reported reductions in platelet count at similar times with exposures to 2987 meters and 5364 meters. One of the factors that may complicate interpretation of coagulation studies at altitude is the physical fitness of the subjects and the amount and degree of physical exertion they undergo since studies have indicated a relationship between severity of exercise and coagulation factors (8). Thus, another aspect of the current study was concerned with the effect of exercise at altitude on several coagulation indicies and the possible influence of the level of physical fitness.

Another aspect of the present study is concerned with visual perception. It has been well documented that elevations of 3000 to 5200 meters produce decrements in dark adaptation, brightness discrimination, and color and flicker sensitivity (9). The importance of visual perception under the stresses of combat and hypoxia cannot be ignored since it bears directly on maneuverability and target detection. The purpose of this phase of the study was to determine the effects of hypoxia on a target detection task not previously used at altitude.

Progress:

Fourteen Army volunteers were recruited, given USARIEM standard altitude physical examinations and divided into two groups based on levels of $\dot{V}O_2$ max. Measurements of anaerobic threshold and $\dot{V}O_2$ max were obtained using an on-line computer system that calculated and displayed $O_2$ consumption, $CO_2$ production, and minute ventilation every 15 seconds while the subjects performed at increasing work loads on a bicycle ergometer. Those subjects with higher $\dot{V}O_2$ max levels underwent a period of 4 weeks physical training consisting of endurance and sprint exercises five days per week. Those subjects with lower $\dot{V}O_2$ max levels did not participate in any physical activities during the same time period.

At the conclusion of the training period, the subjects were tested with respect to the following parameters:

1. $\dot{V}O_2$ max
2. Anaerobic threshold
3. Target detection
4. Blood coagulation
5. Pulmonary function
6. AMS symptomatology questionnaire

They were then transported by air to our Pikes Peak Laboratory Facility (4300 meters) where the same testing protocol was performed after 1, 3, 5 and 7 days. Data collection is now completed and analyses are presently being performed.

Presentations:

None.

Publications:

None.

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|---|---|
| Program Element: | 6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE |
| Project: | 3E762777AB45 Environmental Stress, Physical Fitness and Medical Factors in Military Performance |
| Work Unit: | 051 Prevention and Treatment of Disabilities Associated with Military Operations at High Terrestrial Elevations |
| Study Title: | Changes in Closing Capacity and Lung Volumes during 3 Days of Physical Activity at High Altitude |
| Investigators: | James J. Jaeger, CPT, MSC, John T. Maher, Ph.D., Joseph C. Denniston, MAJ, VC, Jimmie T. Sylvester, MAJ, MC, Allen Cymerman, Ph.D. and Joel J. Berberich, CPT, MSC |

Background:

Clinical high altitude pulmonary edema (HAPE) is a life-threatening situation requiring immediate recognition and medical attention to avert tragedy. Fortunately, the incidence of clinical HAPE among young adults is relatively low (less than 2 %). However, it has been suggested that a form of subclinical HAPE may develop in most individuals exposed to high altitude (8). The primary purpose of this study was to investigate the nature, incidence, and severity of subclinical pulmonary edema in unacclimatized soldiers abruptly committed to a training exercise at high altitude. One of the measures used to detect subclinical pulmonary edema was the lung volume called "closing capacity." Closing capacity as measured by the methods of Buist and Ross (3), is equal to the sum of residual volume and closing volume determined from an analysis of a single breath nitrogen washout curve. It was hypothesized that closing capacity would increase as a result of the accumulation of fluid in the peribronchial and perivascular interstitial spaces. Such fluid accumulation has been shown to occur in the first stages of interstitial pulmonary edema, the precursor of intra-alveolar edema, (5, 9). Fluid accumulation and engorgement of the interstitial spaces would result in displacement of air and possibly an increase in trapped gas volume at low lung volumes.

There is evidence from an animal study to indicate that closing capacity can detect the onset of pulmonary edema before other, more commonly used indices of pulmonary edema such as a decreased vital capacity, displaced pressure-volume curves, and chest roentgenograms (7).

Progress:

A battery of pulmonary function tests to include basic spirometry, closing capacity, quasi-static transpulmonary pressure lung volume curves and chest roentgenograms, were administered to a group of 25 male soldiers who were abruptly exposed to an altitude of 3000 to 4300 meters. Since heavy physical exertion is often associated with the development of HAPE, the assessments of pulmonary function were made before, during and immediately after 3 days of strenuous outdoor activity. In order to account for the effects which this heavy *exercise per se may have had on pulmonary function*, the study was divided into low altitude (LA) and high altitude (HA) phases.

In the low altitude phase, the subjects completed an 84 kilometer hike in the White Mountains of New Hampshire (200 to 875 meters) in a 72-hour period. One week after the completion of the low altitude phase, the same 25 subjects were flown from Massachusetts to Colorado Springs and the Pike National Forest. They immediately began a 72-hour exercise similar to the New Hampshire one. The exercise consisted of a 30 kilometer hike between the 3000 and 4300 meter elevations of Pikes Peak. All measurements were made at the 4300 meter elevation.

At 0, 36, and 72 hours of both the low and high altitude phases, each subject performed 3 acceptable single breath nitrogen washout maneuvers according to the method of Buist and Ross (3). Recordings of inspired and expired volume, nitrogen concentration and transpulmonary pressure from an esophageal balloon, yielded simultaneous records of closing volume and a quasi-static pulmonary compliance curve. From an analysis of the nitrogen washout curve, values for total lung

capacity, vital capacity, residual volume, closing capacity and the slope of phase three were obtained. Except for the compliance data, results were analyzed by a two-way analysis of variance; differences being considered significant at the p .05 level.

Before proceeding to an analysis of the data, it is important to note that based on physical examinations and radiographs, there was no evidence of clinical HAPE in any of the 25 subjects.

Figure 1 depicts the changes observed in total lung capacity during the low and high altitude phases of the study. There was a small but significant increase in total lung capacity during each phase. It is assumed that this increase in lung volume was due to the strenuous physical activity which the subjects performed during the simulated military mission. Similar increases in total lung capacity have been reported by other investigators for athletes in training (6).

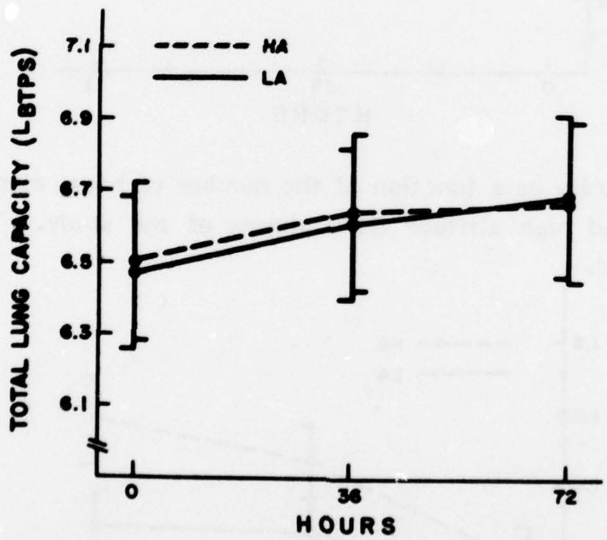


Figure 1. Total lung capacity as a function of the number of hours elapsed during the low altitude (LA) and high altitude (HA) phases of the study. Values are the mean the standard error.

Figures 2 and 3 show the relative changes in vital capacity and residual volume during the two phases of the study. Vital capacity showed a significant progressive decrease with time at high altitude relative to the low altitude values. Since residual volume was calculated as the difference between total lung capacity and vital capacity, it follows that this lung volume increased progressively with time at high altitude and was significantly higher than at low altitude.

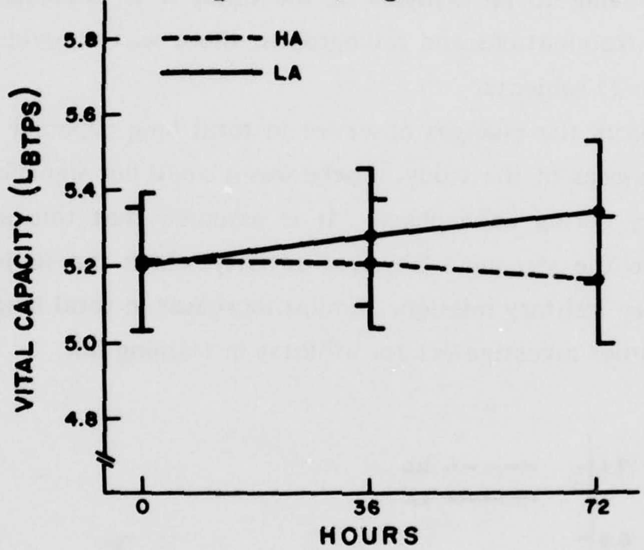


Figure 2. Vital capacity as a function of the number of hours elapsed during the low altitude (LA) and high altitude (HA) phases of the study. Values are the mean ± standard error.

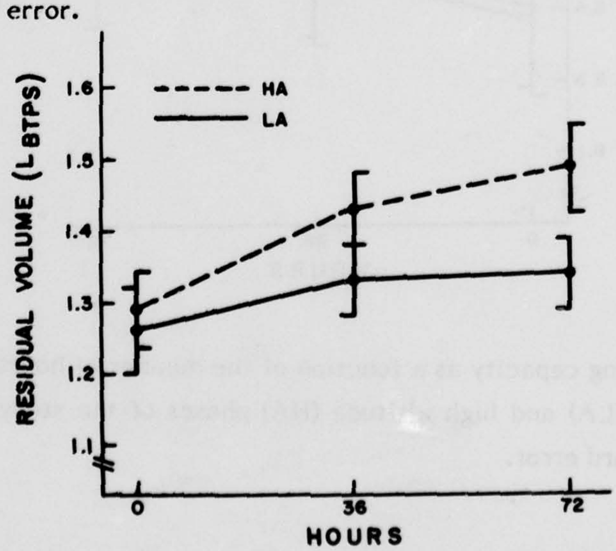


Figure 3. Residual volume as a function of the number of hours elapsed during the low altitude (LA) and high altitude (HA) phases of the study. Values are the mean ± the standard error.

In parallel with the changes in residual volume, closing capacity increased with time at high altitude as shown in figure 4. The difference between the low and high altitude values is significant at the 0.05 level.

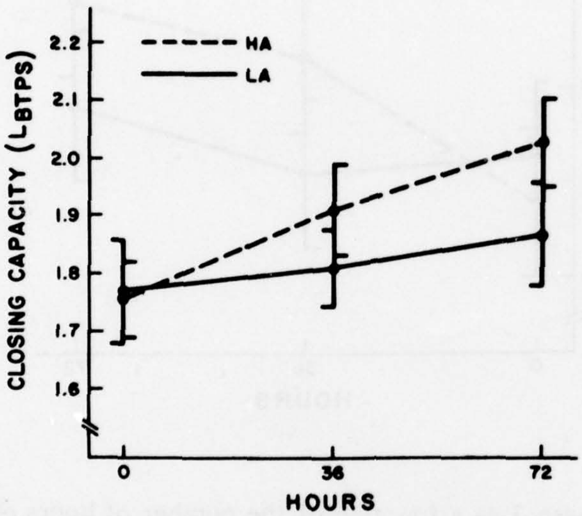


Figure 4. Closing capacity as a function of the number of hours elapsed during the low altitude (LA) and high altitude (HA) phases of the study. Values are the mean ± the standard error.

In contrast to the reports of Gray et al. (4,10), we found no significant change in the slope of phase 3 of the single breath nitrogen washout curve (figure 5). Our negative findings with respect to this parameter would indicate that despite the shifts in pulmonary fluid volume which may have occurred, there was no net effect on intraregional gas concentrations or asynchronous emptying of lung regions. We have reason to believe that the discrepancy between our results and those of Gray et al. can be explained by the inherent alinearity of the nitrogen analyzers used to obtain the nitrogen washout data at high altitude.

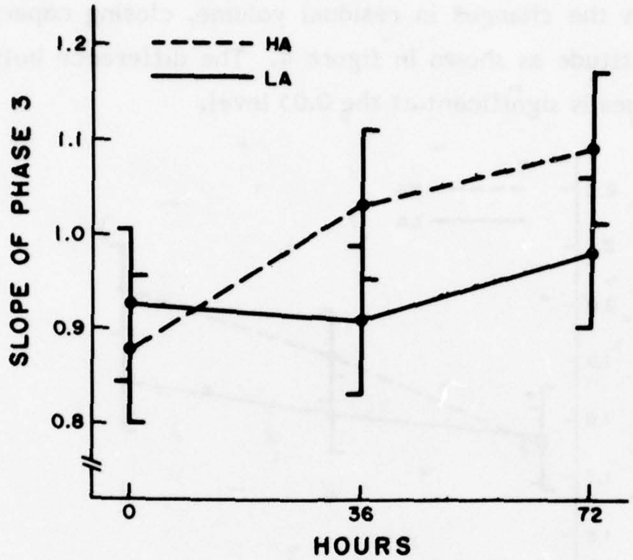


Figure 5. Slope of phase 3 as a function of the number of hours elapsed during the low altitude (LA) and high altitude (HA) phases of the study. Values are the mean ± the standard error.

Figure 6 represents the mean expired limb of the quasi-static pulmonary compliance curve at low and high altitude. These two curves were constructed by plotting the mean lung volume at each of 13 transpulmonary pressures. The data were analyzed by a three-way analysis of variance. The only significant interaction was that for lung volume as a function of altitude and transpulmonary pressure. This interaction is significant at the 0.001 level and indicates that the shape and/or position of these two curves are significantly different. The difference seen in figure 6 between the low and high altitude curves is qualitatively the same as that found for compliance curves obtained during experimentally produced pulmonary edema (1,2).

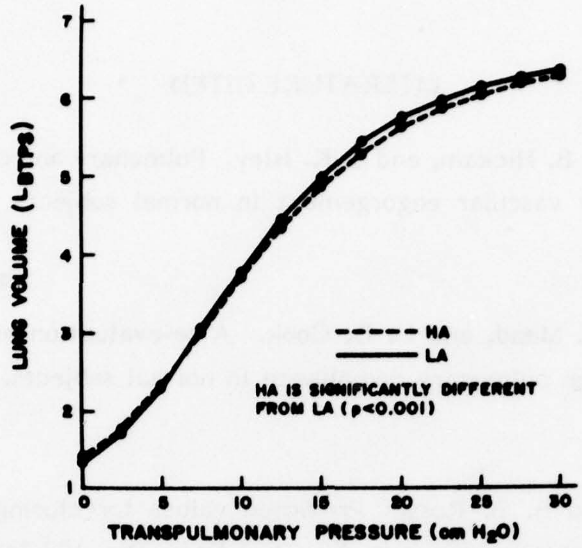


Figure 6. Lung volume as a function of transpulmonary pressure at low altitude (LA) and high altitude (HA). Values are the mean lung volumes of the 0, 36 and 72-hours measurements during each phase of the study.

In summary, on the basis of physical examinations and chest roentgenograms, there was no evidence of clinical high altitude pulmonary edema among any of the 25 subjects participating in the study. However, there were significant and consistent changes in vital capacity, residual volume, closing capacity and the pulmonary compliance curve which are suggestive of the development of interstitial pulmonary edema. An alternative explanation could be that elevated pulmonary arterial pressure due to hypoxic vasoconstriction led to vascular engorgement and the reduction in lung volumes observed.

Presentations:

Jaeger, J. J., J. T. Maher, J. C. Denniston, J. T. Sylvester, A. Cymerman, and J. J. Berberich. Changes in closing capacity and lung volumes during 3 days of physical activity at high altitude. Presented, Annual Meeting, FASEB, Chicago, IL, 4 April 1977. (Fed. Proc. 36:533, 1977).

Publications:

None.

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(83053)

| RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY | 1. AGENCY ACCESSION* | 2. DATE OF SUMMARY* | REPORT CONTROL SYMBOL |
|---|---|---|---|
| | DA OB 6148 | 77 10 01 | DD-DR&E(AR)636 |

| 3. DATE PREV SUM'RY | 4. KIND OF SUMMARY | 5. SUMMARY SCTY* | 6. WORK SECURITY* | 7. REGRADING* | 8a. DISB'N INSTR'N | 8b. SPECIFIC DATA-CONTRACTOR ACCESS | 9. LEVEL OF SUM |
|---|---|---|---|---|---|---|---|
| 77 00 02 | D. Change | U | U | NA | NL | [X] YES [ ] NO | A. WORK UNIT |

| 10. NO./CODES:* | PROGRAM ELEMENT | PROJECT NUMBER | TASK AREA NUMBER | WORK UNIT NUMBER |
|---|---|---|---|---|
| a. PRIMARY | 6.27.77.A | 3E762777A845 | 00 | 053 |
| b. CONTRIBUTING | | | | |
| c. XXXXXXXG | CARDS 114f | | | |

11. TITLE (Precede with Security Classification Code)* (U)Prediction of the Biological Limits of Military Performance as a Function of Environment, Clothing, and Equipment (22)

12. SCIENTIFIC AND TECHNOLOGICAL AREAS*

016200 Stress Physiology; 013400 Psychology; 011700 Operations Research

| 13. START DATE | 14. ESTIMATED COMPLETION DATE | 15. FUNDING AGENCY | 16. PERFORMANCE METHOD |
|---|---|---|---|
| 75 07 | CONT | DA | C. In-House |

17. CONTRACT/GRANT

a. DATES/EFFECTIVE: EXPIRATION:

b. NUMBER:* NOT APPLICABLE

c. TYPE: d. AMOUNT:

e. KIND OF AWARD: f. CUM. AMT.:

| 18. RESOURCES ESTIMATE | | a. PROFESSIONAL MAN YRS | b. FUNDS (In thousands) |
|---|---|---|---|
| FISCAL YEAR | PRECEDING 77 | 5.5 | 217 |
| | CURRENT 78 | 9.0 | 321.2 |

19. RESPONSIBLE DOD ORGANIZATION

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ADDRESS:* Natick, MA 01760

RESPONSIBLE INDIVIDUAL

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TELEPHONE: 955-2811

20. PERFORMING ORGANIZATION

NAME:* USA RSCH INST OF ENV MED

ADDRESS:* Natick, MA 01760

PRINCIPAL INVESTIGATOR (Furnish SSAN if U.S. Academic Institution)

NAME:* GOLDMAN, Ralph F., Ph.D.

TELEPHONE: 955-2831

SOCIAL SECURITY ACCOUNT NUMBER:

ASSOCIATE INVESTIGATORS

NAME: PANDOLF, Kent B., Ph.D.

NAME: STROSCHEIN, Lee DA

21. GENERAL USE

Foreign Intelligence Not Considered

22. KEYWORDS (Precede EACH with Security Classification Code) (U)Environmental Tolerance; (U)Performance Limits; (U)Energy Expenditure; (U)Terrain Coefficients; (U)Dehydration

23. TECHNICAL OBJECTIVE.* 24. APPROACH. 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)

23. (U)Develop and validate by physiological studies, mathematical models which synthesize information on military task requirements and the interaction between man, his clothing and equipment, and the environment, to predict mission performance capability and identify areas where additional information is needed.

24. (U)Predictive models of heat production and loss, subjective sensation, and limiting criteria in terms of maximum work capacity as well as unsafe levels of extremity temperature and/or body heat content are evaluated. Systems for predicting individual comfort and unit mission performance decrements and tolerance time are developed from these models. Results are validated in chamber and field trials, involving human volunteers as subjects, and guide clothing and equipment design, suggest tactical doctrine, and indicate potential environmental casualties.

25. (U)76 10 - 77 09 Problems of human subject use have limited physiological studies this year, so work was directed to collating and publishing the results of previous studies, to refining theoretical models of evaporative heat transfer, dehydration and oversnow mobility, to collecting data from the limited open literature on tuese topics and to improving the software of our prediction approaches. A revised model which will predict march rate, or alternatively endurance at a specified march rate has been formulated; data is being collected from past studies at the Institute and in the open literature, to characterize the maximum work capacity of various military populations as a function of age, sex and physical condition description.

*Available to contractors upon originator's approval

DD FORM 1498, 1 MAR 68 — PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE. DD FORMS 1498A, 1 NOV 65 AND 1498-1, 1 MAR 68 (FOR ARMY USE) ARE OBSOLETE



U.S. GPO: 1974-540-843/8691

| | |
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| Program Element: | 6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE |
| Project: | 3E762777AB45 Environmental Stress, Physical Fitness and Medical Factors in Military Performance |
| Work Unit: | 053 Prediction of the Biological Limits of Military Performance as a Function of Environment, Clothing and Equipment |
| Study Title: | Studies on the Energy Cost of Load Carriage Considering Slow Walking Speeds and Standing |
| Investigators: | Kent B. Pandolf, Ph.D., Fred R. Winsmann and Ralph F. Goldman, Ph.D. |

## Background:

Previous work at this Institute has led to the development of a mathematical model which enabled prediction of the metabolic cost of walking and load carrying (2). The main factors included in the model were: weight of the subject (W), external load carried (L), the speed of walking (V), the grade of the slope (G - in percent), and the nature of the terrain, expressed by a factor ($\eta$). This model had a lower limit for speed (0.7 m/s = 2.5 km/hr = 1.5 mph), above which it was applicable. It seemed desirable to extend the range of speed to zero (standing) and to include the metabolic cost of load carrying while standing. The practical importance of this modification is apparent when the mandatory pace ($< 0.7$ m/s) for prolonged walking on some terrains, such as soft snow, is considered. Taking into account the above considerations, a revised model has been developed which includes the total range of walking speeds.

## Progress:

Two studies have been completed. The first involved external loads of 32, 40 and 50 kg (50 kg = 110 lbs) carried at either 1.0, 0.8, 0.6, 0.4, 0.2 m/s (1.5 mph = 0.7 m/s). The second involved measuring energy cost of standing with 10, 30, and

50 kg loads. A new energy cost prediction equation has been developed for walking which considers load carriage. This model consists of four components: (a) a metabolic cost for standing without load ($M_1$), which is proportional to the weight of the body and is calculated as 1.5 watt per kilogram of body weight ($M_1 = 1.5W$); (b) a metabolic cost of load bearing while standing ($M_2$), which is affected by the total weight (subject + load) and is fitted as a function of the load to weight ratio squared $M_2 = 2.0\ (W + L)\ (L/W)^2$ ; (c) a metabolic cost for walking on the level ($M_3$), which is related to a specific terrain ($\eta$), considers total weight moved and is a function of the speed squared $M_3 = \eta(W + L)\ (1.5V^2)$ ; (d) a metabolic cost for climbing a grade ($M_4$), which again considers a specific terrain ($\eta$) and total weight, and is a linear function of the speed and grade $M_4 = \eta\ (W + L)\ (0.35VG)$ . However, this component ($M_4$) will require further validation at speeds less than 0.7 m/s. Thus, the analysis of the studies cited above which considered these four components, led to the revised prediction formula:

$$M = 1.5W + 2.0(W + L)\ (L/W)^2 + \eta(W + L)\ [1.5V^2 + 0.35VG]$$

where:

$M$ = metabolic rate, watt

$W$ = subject weight, kg

$L$ = external load, kg

$V$ = speed of walking, m/s

$G$ = grade (slope), %

$\eta$ = terrain coefficient ($\eta = 1.0$ for treadmill)

Since the old energy expenditure prediction formula (2) was compared to experimental studies of many different investigators, using different subjects walking at different speeds, grades and carrying different loads, it seemed appropriate to compare the new formula to the old one. Figure 1 compares projected energy expenditures (M) at various walking speeds (V) and grades (G), for a 70 kg individual carrying a 30 kg load while walking on a treadmill utilizing the old and new prediction formula. Differences in energy expenditure between formulas at equivalent grades are very small, with the greatest differences being at the higher grades (i.e., 16 and 24%). Also, there is some deviation between

formulas near the lower predictive limit (0.7 m/s) of the old formula.

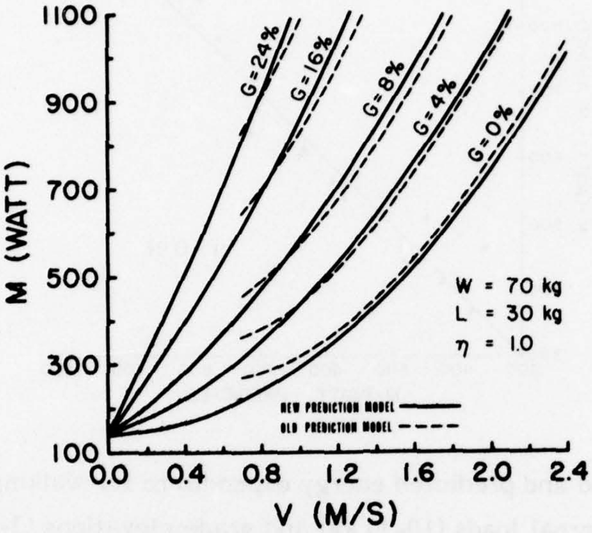


Figure 1. Comparison projected energy expenditure of an individual (70 kg), while carrying a 30 kg external load, at various grades throughout the entire range of walking speeds utilizing old (2) and new prediction formula.

The validity of the new predictive formula was checked by comparing the predicted with the measured energy expenditures in the study of Goldman and Iampietro (1). The walking speed (0.7 - 1.8 m/s), load carried (10-30 kg) and percent grade (3 - 9%) offered a wide range of energy expenditure values. The correlation coefficient (r) between the predicted and measured values is presented in Figure 2. This coefficient (r = 0.96) is identical to that calculated and presented from the old formula (2).

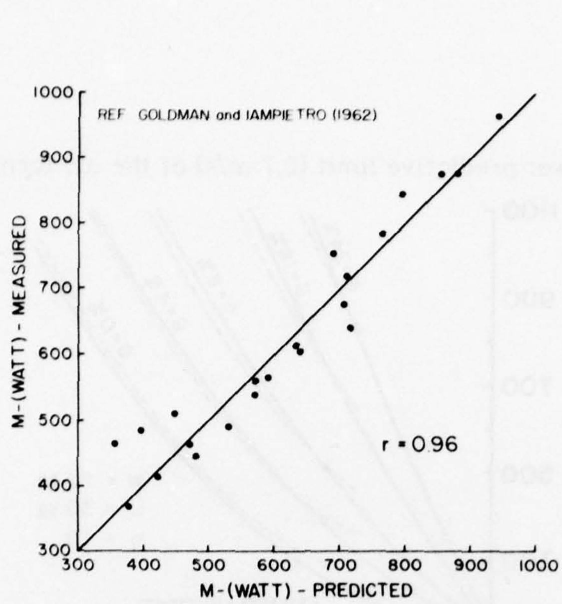


Figure 2. Measured and predicted energy expenditure for walking at various speeds (0.7 - 1.8 m/s), external loads (10-30 kg) and grade elevations (3-9%). Reference is to work by Goldman and Iampietro (1).

The new predictive model has shown good agreement between measured and predicted values. The new model allows prediction for slow walking speeds down to standing, with consideration for load carriage. The new predictive model not only extends the range of application beyond that of the old one, but also is more simplified in its mathematical form and enables hand computation of the metabolic rate. This last factor may greatly facilitate its application.

In another study, we have evaluated the energy expenditure of heavy load carried. Fourteen subjects (22 yr, 175 cm, 72 kg) walked for 20 min on a treadmill at 0.89, 1.33 or 1.78 m/s carrying 35, 40, 45, or 50 kgs; during a second phase, ten additional subjects (22 yr, 178 cm, 75 kg) attempted to walk for 45 minutes at the same speeds carrying 60, 65, or 70 kg. Energy expenditure when expressed as milliliters of oxygen per minute per kilogram of total weight (man + clothing + load) agreed, for the no load condition, with literature values. After deducting the individual's no load cost, the resulting net energy expenditure for carrying the loads, when expressed as ml/kg min was generally constant at each

speed; i.e., loads from 35 to 70 kg showed no statistical differences in energy expenditure per kilogram at 0.89 and 1.33 m/s (see Table 1). At 1.78 m/s carrying 70 kg, the average measured cost per kg was statistically different ($p<.05$) than carrying 35 kg; at this speed subjects were working at greater than 90% of their maximal $\dot{V}O_2$ levels carrying 70 kg (Table 1). However, similar comparison at 1.78 m/s of the measured cost per kg between loads of 40 and 65 kg showed it was statistically the same. The general constancy of measured energy expenditure per kg for loads even up to 70 kg, probably depends on the condition that the load is well balanced and close to the center of the body. As reported earlier, higher costs are associated with loads in unbalanced positions. Thus, the limitations commonly encountered in load carrying capacity may arise from inefficiencies of load position rather than from the weight of the load per se. This predictive capacity for carrying heavy loads will be added to our new prediction equation.

Table 1. The expenditure per kilogram of body plus clothing weight when walking, expressed in milliliters of oxygen per kilogram per minute, and the additional milliliters of oxygen per minute allocated per kilogram of additonal weight, for each of the load conditions. Values given are the mean ( ±1 standard error) of 14 subjects (35, 40, 45, 50 kg) and of 10 subjects (60, 65, 70 kg).

| Condition | Speed in meters per second (m/s) | | |
|---|---|---|---|
| | 0.89 | 1.33 | 1.78 |
| **Phase I** | | | |
| (n = 14) | | | |
| No load | 8.7 (±0.3) | 12.0 (±0.3) | 17.9 (±0.6) |
| 35 kg load | 14.6 (±1.9) | 18.7 (±2.4) | 32.1 (±3.9) |
| 40 kg load | 12.9 (±1.4) | 19.8 (±1.3) | 29.5 (±2.5) |
| 45 kg load | 11.3 (±1.6) | 18.6 (±1.5) | 28.7 (±2.5) |
| 50 kg load | 13.2 (±1.2) | 18.9 (±1.7) | 29.4 (±2.2) |
| **Phase II** | | | |
| (n = 10) | | | |
| No load | 10.6 (±0.3) | 14.7 (±0.7) | 20.6 (±0.5) |
| 60 kg load | 9.3 (±0.6) | 13.7 (±1.4) | 25.0 (±2.6) |
| 65 kg load | 9.8 (±1.0) | 14.9 (±1.1) | 23.8 (±2.0) |
| 70 kg load | 10.7 (±1.6) | 14.3 (±2.0) | 22.1 (±1.2) |

Prediction of the energy cost of running with and without loads, on laboratory and natural surfaces, will be initiated. Modifications considering the energy expenditure for standing and slow walking up and down grades will also be considered.

Presentations:

1. Pandolf, K. B., J. G. Esler, A. Mroczek, B. Givoni and R. F. Goldman. Predicting Energy Expenditure Considering Efficiency of Load Carriage at Very Slow Speeds. Federal Proceedings, 35(3):529, 1976.

2. Pandolf, K. B., B. Givoni and R. F. Goldman. Predicting Energy Expenditure for Various Jobs. Paper delivered at Brouha Work Physiology Symposium, Stone Mountain Park, Georgia, September 14, 1976.

Publications:

1. Pandolf, K. B., B. Givoni and R. F. Goldman. Predicting Energy Expenditure with Loads while Standing or Walking Very Slowly. Journal of Applied Physiology (in press).

2. Soule, R. G., K. B. Pandolf and R. F. Goldman. Energy Expenditure of Heavy Load Carriage. Ergonomics (in press).

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2. Givoni, B., and R. F. Goldman. Predicting metabolic energy cost. J. Appl. Physiol. 30:429-433, 1971.

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| Program Element: | 6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE |
| Project: | 3E762777AB45 Environmental Stress, Physical Fitness and Medical Factors in Military Performance |
| Work Unit: | 053 Prediction of the Biological Limits of Military Performance as a Funcion of Environment, Clothing and Equipment |
| Study Title: | Hard Work for Walking on Snow of Various Depths |
| Investigators: | Kent B. Pandolf, Ph.D., Fred R. Winsmann and Ralph F. Goldman, Ph.D. |

## Background:

In a previous study, the metabolic energy expenditure and terrain coefficients for walking on snow were determined using 6 male volunteer subjects. These subjects each walked for 15 minutes at each of two fix-paced speeds, 0.67 and 1.12 m/s (1.5 and 2.5 mph), on a treadmill (level) and on a variety of snow depths. Energy expenditure increased linearly with increasing depth of footprint depression, reaching a ratio of about 5:1 when a 45 cm footprint depression was compared to 0 cm depression. Although these subjects were considered above average in terms of physical fitness mean $\dot{V}O_2$ max = 51.4 ml/kg·min, ,all stopped walking because of exhaustion at an average footprint depth of 35.0 cm at a walking speed of 1.12 m/s. Practical limits for snow walking without snowshoes not exceeding about 50% $\dot{V}O_2$ max were developed, with 20 cm being the maximal depth at 0.67 m/s and 10 cm at 1.12 m/s (3).

Certainly, walking on snow is a very tiresome form of human locomotion (1, 2, 3). However, little is known about the self-paced work rates soldiers would adopt as "hard work" for prolonged durations of snow walking. The present study was initiated to provide information about (a) the measured steady-state energy expenditure for self-paced snow walking at various snow footprint depths and (b) the effect of load carrying (backpack) on self-pacing at various snow depths.

Progress:

Seven healthy male volunteers, from the Institute staff, each less than 30 years of age, first had a determination of their maximal oxygen uptake performed on a treadmill in the laboratory. They walked at 1.56 meters per second (3.5 mph) on a level treadmill; the grade was increased by 2.5% every 2 minutes. Heart rate was determined from a continuously recorded electrocardiogram. At and above a heart rate of 160 beats/min, expired air samples were obtained during the last minute of each grade elevation. A plateau in calculated oxygen uptake (sample differences of less than 150 ml/min or 2.1 ml/kg·min) increase established the subject's maximum $\dot{V}O_2$. The mean (± SE) maximal oxygen uptake for these seven subjects was 3.69 ± 0.16 l/min (46.55 ±2.01 ml/kg·min).

In the second part of the study, the subjects will each walk a mile outdoors in 3-5 different depths of snow (up to approximately 50 cm (20 inches) deep). Subjects will walk at a self-determined, voluntarily "hard" pace which they are able to sustain for 2-4 hours under each of 3 load conditions: in field clothing, and combat boots, but without backpack; with a 10 kg backpack; and with a 20 kg backpack. At each quarter mile, expired gas samples will be collected in a Max Planck gasometer for 4 minutes; these will be analyzed for oxygen and the results used to determine energy expenditure. Heart rate will be determined by radial pulse count, for 30 seconds after each quarter-mile walk. After each walk, the temperature, wind velocity, snow-water content, and the depth of footprint depression in the snow will be measured. Techniques and calculations will be as reported by Pandolf et al. (3). This phase of the study, weather permitting, should be completed during the winter months of fiscal year (FY 78).

Presentations:

1. Goldman, R. F., M. F. Haisman and K. B. Pandolf. Metabolic Energy Cost and Terrain Coefficients of Walking on Snow. Paper delivered at the Third International Symposium on Circumpolar Health, Yellowknife, Northwest Territory, (Cda) July 8-11, 1974.

2. Pandolf, K. B., F. R. Winsmann, M. F. Haisman and R. F. Goldman. Metabolic Energy Expenditure and Terrain Coefficients for Walking on Snow. The Physiologist, 17(3):301, 1974.

Publications:

Pandolf, K. B., M. F. Haisman, and R. F. Goldman. Metabolic Energy Expenditure and Terrain Coefficients for Walking on Snow. Ergonomics, 19(6):683-690, 1976.

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| Program Element: | 6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE |
| Project: | 3E762777AB45 Environmental Stress, Physical Fitness and Medical Factors in Military Performance |
| Work Unit: | 053 Prediction of the Biological Limits of Military Performance as a Function of Environment, Clothing, and Equipment |
| Study Title: | Establishing Terrain Coefficients for Predicting the Energy Cost of Oversnow Movement Aided by Military Skis and Snowshoes |
| Investigator: | Richard L. Burse, Sc.D. |

Background:

Previous studies in the Military Ergonomics Division have defined coefficients for predicting the energy cost of walking in combat boots at a fixed pace on specific terrains, relative to the energy cost of walking on treadmills (1,2). Coefficients for 6 terrains devoid of snow were first established (3,4). Recently, coefficients for walking in snow have been defined as a function of the depth of footprint (2) to extend the energy cost of prediction equation for military foot movement reported in 1971 (1) to include oversnow movement in Arctic footwear, with skis and snowshoes, coefficients are needed for the energy cost of:

a. Fixed-pace snow walking in the current Army standard cold-dry vapor barrier boot.

b. Fixed-paced snowshoeing and cross-country skiing, utilizing current Army standard equipment.

Progress:

It is expected that the energy cost will be greater due to the added weight of the footwear and oversnow equipment (3), but the added cost cannot be predicted

accurately because of differences in traction, penetration in the snow and snow-loading of skis and snowshoes. Although the energy cost of oversnow movement on skis and snowshoes of civilians has been reported in the literature, these reports cannot serve as a data base for prediction because the subjects are generally very skillful, highly fit subjects of varying ages, most often using recreational or competitive equipment which is much lighter in weight than that provided the less experienced U. S. soldier.

Subjects will undergo a progressive running maximum oxygen uptake test (5) in the laboratory until a plateau in uptake is reached to determine their maximum aerobic capacity. The field determination of metabolic rate will be carried out on level terrain of adequate area to permit 10 min of movement by each of the subjects wearing each footwear combination at each speed in a factorial design: standard vapor barrier boot (a) alone, (b) with snowshoe and (c) with skis. Speeds will be as follows: footwear alone: 27, 40 and 54 m/min (1.0, 1.5,and 2.0 mi/hr), snowshoes: 27, 40 and 54 m/min, Skis: 54, 80 and 107 m/min (2, 3 and 4 mi/hr). Snow depth will be greater than 20 cm for skiing and snowshoeing and will be as close as possible to 20, 30 and 40 cm (8, 12 and 16 inches) for walking in footwear alone. Pack weight will be 0, 10 and 20 kg in addition to the clothing and equipment weight of about 11 kg. Snow characteristics (water content, density, etc.) will be measured and an attempt will be made to measure the weight of any accumulation of snow on the footwear. The raw energy cost data for each subject will be entered into the energy cost equation of Givoni and Goldman and an average terrain coefficient will be calculated at each speed and pack weight for snowshoeing and skiing, and for walking in standard footwear at each snow depth. The snowshoeing and skiing coefficients can be used directly for prediction of energy cost and, subject to additional validation, for prediction of oversnow mobility. The coefficients at each depth when walking will be graphically analyzed to determine the relationship between snow depth and relative energy cost to permit interpolation of coefficients at depths not measured directly.

During the 1976-77 winter, the maximum oxygen consumption of seven male subjects was assessed (mean ± SD = 3.69 ± 0.43 l/min; 46.55 ± 2.01 ml/min - kg) prior to 3 weeks ski training in snow depths of 6-10 cm. An early thaw destroyed

the ski-track, necessitating deferment of further data collection for the study on movement skis only until the 1977-78 winter.

The same subjects have been recruited again for FY 78 and have been maintaining their physical fitness. After refresher ski training, the energy cost of movement on skis will be determined at different speeds and loads. The energy cost of snowshoeing and snow walking in standard arctic boots will be assessed during future winters.

Presentations:

None.

Publications:

None.

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| Program Element: | 6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE |
| Project: | 3E762777AB45 Environmental Stress, Physical Fitness and Medical Factors in Military Performance |
| Work Unit: | 053 Prediction of the Biological Limits of Military Performance as a Function of Environment, Clothing, and Equipment |
| Study Title: | The Energy Cost of Novices during Cross-Country Skiing |
| Investigators: | Fred R. Winsmann, Amy Goldstein, and Richard L. Burse, Sc.D. |

## Background:

Previous research at US Army Research Institute of Environmental Medicine (USARIEM) has established coefficients for predicting the energy cost of walking in combat boots at a fixed pace on various terrains, relative to the energy cost of walking on treadmills. Coefficients for six specific terrains (blacktop road, dirt road, light brush, heavy brush, swamp, sand) devoid of snow were first determined in 1972 (4). More recently, coefficients for walking in snow have been defined as a function of the depth of footprint (2). The purpose of this study was to determine coefficients for the energy cost of fixed-paced cross-country skiing, utilizing current Army standard equipment with novice (untrained) skiers.

We require this information in order to extend the energy cost prediction equation for military foot movement (1) to include oversnow movement in Arctic footwear, with and without skis. We expect that the energy cost will be greater due to the added weight of the footwear and oversnow equipment, as shown by previous research (3), but the additional cost cannot be accurately predicted because of differences in traction, penetration into the snow and snow-loading of skis.

The energy cost of oversnow movement on skis has been reported in the literature, particularly in some foreign reports on their populations. Unfortunately, these reports cannot serve as a data base for prediction because their subjects are generally very skillful, highly fit, civilian subjects, most often using recreational or

competitive equipment which is much lighter in weight than the rugged equipment provided the less-well trained U. S. soldier.

Progress:

This particular study attempted to assess the rate of acquisition of skill on skiers from measurement of how energy costs changed with each day of the initial training of novices. This study was conducted during winter around the perimeter of a baseball field using four volunteer novice cross-country skiers as subjects for 30 minutes every morning over a four day period. The mean age, height and weight of the group was 21.2 yrs., 174.6 cm., and 71.02 kg. Subjects wore the standard Army Arctic uniform (modified), including the leather glove with wool insert and the white Arctic insulated boot. The test course was a 792 foot circular course of pre-packed snow with half minute flag markers 132 feet apart (to be reached in 30 seconds), and one minute flag markers each 264 feet (to be reached in one minute). The flag markers enabled an experienced pace—setter to establish the fixed-pace rate of 3.0 mph (264 feet/min). Two subjects at a time skied around the course. They used the standard Army combination cross— country and downhill, seven foot long, fiberglass ski.

On the day prior to the outdoor study, the subjects were tested in a climatic chamber (O°C) walking on a treadmill at 3.0 mph for 30 minutes to obtain base-line energy consumption measurements and to familiarize subjects and investigators with procedures and measurement techniques. They wore the identical clothing ensemble (with exception of skis and poles) that was worn outside and carried a Max Planck gasometer on their backs for collecting expired gas samples for analysis on the Beckman E-2 oxygen analyzer. As on the outdoor course, three gas samples per 30 minute run were collected. Heart rates were measured before and after each run as an indicator of exertion. Daily measurements of the weather conditions and snow characteristics (water content, density, etc.) were taken at the outdoor ski course.

The weather and course conditions for the four days of testing were as follows:

Day 1- Air Temp 6.5°C; the course was getting slushy as the ice base was melting and the old snow was soft.

Day 2- Air Temp 0.5°C DB; it was snowing all morning, and the course was very icy and slippery.

Day 3- Air Temp 5.5°C DB; the course was hard, dry packed snow.

Day 4- Air Temp 10.0°C DB; the course was hard, dry packed snow with an ice base, the best it had been all week.

The average energy expended by the four novice cross-country skiers over the four day testing period were: Day 1-617, Day 2-718, Day 3-579 and Day 4-526 kcal/hr respectively. From statistical analysis, the Day 2 level was significantly higher than all other days, Day 1 was greater than Day 4 with a critical difference at the $p<.01$ level of 85 kcal/hr.

When kcal/hr means were plotted against gas sample collection time, there was a critical difference at the .05 probably level equaling 29 kcal/hr; Time 1 (6-10 min) was greater than Time 2 (16-20 min). These values were: Time 6-10 min-630 kcal/hr, Time 16-20 min-595, Time 26-30 min-605. The terrain coefficients for the fourd ays were: Day 1-1.83, Day 2-2.14, Day 3–1.73 and Day 4–1.56.

In the analysis of the data, it was shown that on Day 2 the energy expenditure was greater than all other days. Since we would expect a drop in energy cost with time (due to training effects of the novice skiers), this rise was probably due to the more severe weather conditions on Day 2. The mean heart rates of the subjects were also higher on Day 2, and the subjects appeared to be having difficulty maneuvering due to the weather on this day. It was also shown, in the analysis, that the energy cost from 6-10 min (Time 1) was greater than that from 16-20 min (Time 2). This was expected as the subjects "learned" to become more mechanically efficient; they became less clumsy with time and apparently used less muscle mass. However, there was no statistical significance found between time 3 (26-30 min) and the earlier collection periods, perhaps because of fatigue effects.

The terrain coefficients established for energy cost prediction are as follows (4):

| | | | |
|---|---|---|---|
| | Treadmill 1.0 | | |
| Blacktop Road | 1.0 | Heavy Brush | 1.5 |
| Dirt Road | 1.1 | Swamp | 1.8 |
| Light Brush | 1.2 | Sand | 2.1 |

The terrain coefficient on Day 1 of this study correlates to walking in the swamp (1.83); Day 2 in the sand (2.14); Day 3 in between heavy brush and swamp (1.73); and Day 4 heavy brush (1.56). The overall average for the study is equal to the coefficient for swamp (1.82). This study was done on a prepacked course, and the terrain coefficients were quite high. If soldiers were breaking trail over loose, soft snow, the energy cost would have been even greater.

The findings on this preliminary study focus on some important problems that must be faced in establishing terrain coefficients for predicting the energy cost of oversnow movement aided by military skis and snowshoes (i.e. changing weather conditions, learning curves for untrained troops, effects of snow characteristics, ideal pace for oversnow movement, etc.). These and other problems will be addressed in future research using a larger sample over a longer period of time.

Presentations:

None.

Publications:

None.

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2. Pandolf, K. B., M. F. Haisman and R. F. Goldman. Metabolic energy expenditure and terrain coefficients for walking on snow. Ergonomics 19:683–690, 1976.

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4. Soule, R. G. and R. F. Goldman. Terrain coefficients for energy cost prediction. J. Appl. Physiol. 32:706-708, 1972.

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| Program Element: | 6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE |
| Project: | 3E762777AB45 Environmental Stress, Physical Fitness and Medical Factors in Military Performance |
| Work Unit: | 053 Prediction of the Biological Limits of Military Performance as a Function of Environment, Clothing and Equipment |
| Study Title: | The Convergence of Rectal and Skin Temperature as a Criterion of Heat Tolerance |
| Investigators: | Kent B. Pandolf, Ph.D. and Ralph F. Goldman, Ph.D. |

## Background:

Many laboratories, in addition to US Army Research Institute of Environmental Medicine (USARIEM), use criteria of rectal temperature ($T_{re}$: at USARIEM $39.5^{o} \pm 0.5^{o}C$) and/or heart rate (HR: 180 beats/min  10%) as tolerance limits for men working in the heat (2, 3, 4, 5, 6). In earlier work from this Institute, it was suggested that mean skin temperature ($\bar{T}_{sk}$) after 10 minutes of exposure was a prognosticator of the tolerance time for men working in hot environments. More recently, having acquired the ability to simultaneously plot on-line both rectal and skin temperatures of each subject during experimentation, we have been impressed with the extent to which convergence of $\bar{T}_{sk}$ toward $T_{re}$ indicates a decreasing tolerance time. We felt that the convergence might be a better, and certainly more comfortable indicator of approaching intolerance than either $T_{re}$ or HR, alone or in combination.

## Progress:

Data from two studies suggest that the convergence of $\bar{T}_{sk}$ and $T_{re}$ can indeed be a reliable indicator of decreasing tolerance time, and a voluntary tolerance limit for individuals. Both studies ($S_1$ and $S_2$) involved young, fit soldiers who were heat acclimatized for 5 to 7 days. During $S_1$, involving protective clothing systems, 7 subjects were tested in both a hot-dry ($46^{o}C$, 10% rh) and hot-

wet (35$^{o}$C, 75% rh) environment with 1.1 m/s wind and 0.11 Watt/cm$^{2}$·hr radiant heat load. These subjects carried out a variety of physical activities each day for 120 minutes. During $S_2$, six different rainsuits were evaluated in a hot-dry environment (49$^{o}$C, 20% rh). In these experiments, 6 subjects attempted a 50 minute walk at 1.34 m/s on the treadmill followed by a 30 minute rest.

In $S_1$ while wearing a completely impermeable, unventilated protective garment, convergence of $\bar{T}_{sk}$ on $T_{re}$ led to early voluntary experimental termination in both the hot-dry (mean $T_{re}$ = 38.3$^{o}$C, HR = 142 beats/min, time = 37 min) and hot-wet phases; (mean $T_{re}$ = 38.7$^{o}$C, HR = 166 beats/min, time = 65 min). During $S_2$, test exposures in 4 rainsuits were also terminated upon convergence of $\bar{T}_{sk}$ on $T_{re}$ (despite mean $T_{re}$ = 38.4$^{o}$C, HR = 166 beats/min, time = 33 min). Note that, in all cases, subjective tolerance occurred at $T_{re}$ and HR well below the usual tolerance criteria.

A comprehensive data analysis of all results ($S_1$ and $S_2$) indicated that convergence of predicted $T_{re}$ rise (1) and projected $\bar{T}_{sk}$ rise (linear regression of initial $\bar{T}_{sk}$ values) matched (± 5 min) actual convergence. This approach for predicting the convergence of $\bar{T}_{sk}$ on $T_{re}$ and the individual tolerance limits expected while working in the heat in semi-permeable or impermeable clothing is displayed in Figure 1.

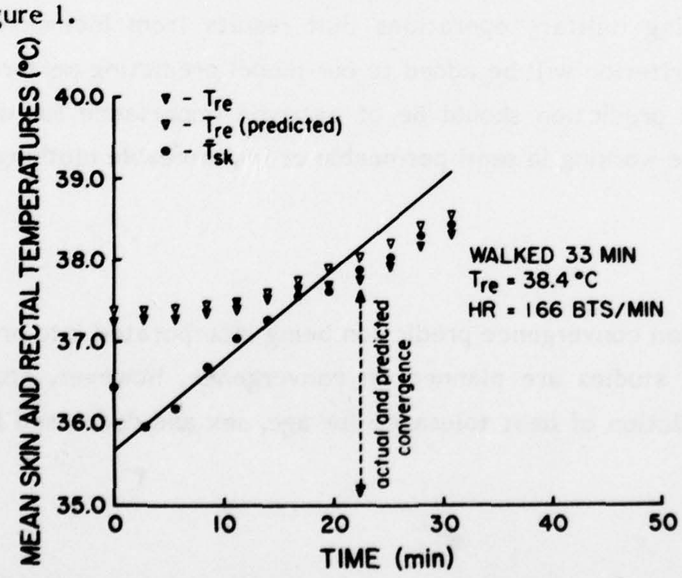


Figure 1. Predicted and observed convergence of mean skin ($\bar{T}_{sk}$) and rectal ($T_{re}$) temperatures ($^{o}$C) used to determine an individual's tolerance limit. Predicted $T_{re}$ computed according to Givoni and Goldman (1); linear regression of $\bar{T}_{sk}$ calculated by least squares method (r = 0.98).

Thus, both the observed and predicted convergences agree quite well with the subjective symptomatology for impending collapse used to determine the individual tolerance limits. This approach for predicting safe exposure and tolerance time, while working in heat where evaporative cooling is greatly reduced (semi-permeable and impermeable clothing), has many advantages. First, individual differences are minimized because each individual serves as his own control. Prior to such exposures, $T_{re}$ can be predicted quite accurately for a fit, young man considering such variables as his height, weight, work load, external load, clothing characteristics (clo, $i_m$/clo), the state of acclimatization, wet and dry bulb temperatures and wind speed to mention only some of the variables; factors to adjust for sex, age and decreased fitness are needed for this or any other approach, and are being developed. During these severe exposures, the $\bar{T}_{sk}$ rises rapidly and quite linearly ($r = 0.90 - 0.99$). Linear regression of the initial $\bar{T}_{sk}$ can be accurately extrapolated to intersect the previously plotted, predicted $T_{re}$ response. Thus, predicted tolerance time based on convergence of $\bar{T}_{sk}$ on $T_{re}$ would be known far in advance of the actual convergence and the associated medical problems.

The improved prediction of the occurrence of heat stress and/or heat casualties during military operations that results from inclusion of a $T_{re} - \bar{T}_{sk}$ convergence criterion will be added to our model predicting performance capacity. This improved prediction should be of extreme importance for determining heat tolerance while working in semi-permeable or impermeable clothing.

Future Plans:

Other than convergence prediction being incorporated into prediction models, no addiitional studies are planned on convergence, however, studies on factors adjusting prediction of heat tolerance for age, sex and decreased fitness are being planned.

Presentations:

1. Pandolf, K. B. and R. F. Goldman. Convergence of Skin and Rectal Temperatures as a Criterion for Heat Tolerance. The Physiologist, 18(3):343, 1975.

2. Pandolf, K. B. and R. F. Goldman. The Convergence of Skin and Rectal Temperatures as a Criterion for Heat Tolerance. XXVIIth International Congress of Physiological Sciences Lille Satellite Symposium on Temperature Regulation (Abstracts), Lille, France, July 13, 1977, pp. 38.

Publications:

Pandolf, K. B. and R. F. Goldman. The Convergence of Skin and Rectal Temperatures as a Criterion for Heat Tolerance. Proceedings of the 1977 Satellite Symposium on Temperature Regulation, Lille, France (in press).

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4. Pandolf, K. B., R. R. Gonzalez and A. P. Gagge. Physiological strain during light exercise in hot-humid environments. Aerospace Med. 45:359-365, 1974.

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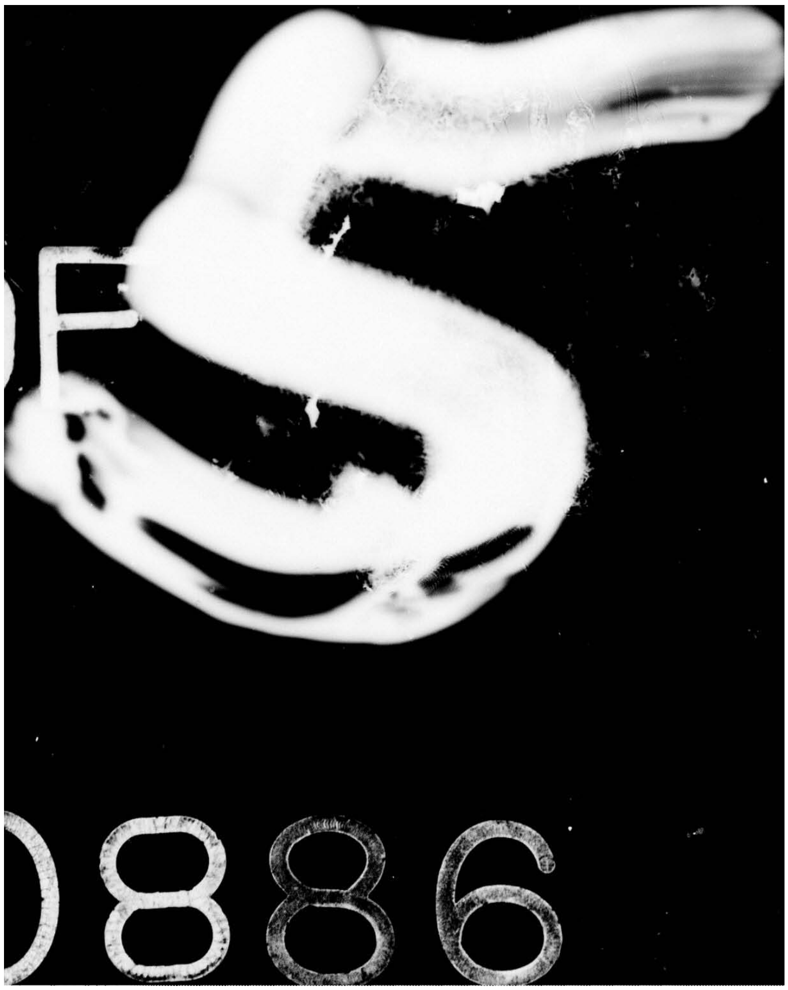
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2. Pandolf, K. B. and R. F. Goldman. The Convergence of Skin and Rectal Temperatures as a Criterion for Heat Tolerance. XXVIIth International Congress of Physiological Sciences Lille Satellite Symposium on Temperature Regulation (Abstracts), Lille, France, July 13, 1977, pp. 38.

Publications:

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4. Pandolf, K. B., R. R. Gonzalez and A. P. Gagge. Physiological strain during light exercise in hot-humid environments. Aerospace Med. 45:359-365, 1974.

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| Program Element: | 6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE |
| Project: | 3E762777AB45 Environmental Stress, Physical Fitness and Medical Factors in Military Performance |
| Work Unit: | 053 Prediction of the Biological Limits of Military Performance as a Function of Environment, Clothing and Equipment |
| Study Title: | Role of Dehydration in Limiting Human Performance While Working in the Heat |
| Investigators: | Kent B. Pandolf, Ph.D., Richard L. Burse, Sc.D., Baruch Givoni, Ph.D. and Ralph F. Goldman, Ph.D. |

Background:

Effects of dehydration on body temperature and heart rate (HR) responses of men during work at one hot environmental condition and work level have been reported (1). Results of these earlier studies suggested that the rate of rise of rectal temperature ($T_{re}$) was increased by roughly 0.1°C per 10 minutes for each percent of dehydration (reduction in initial whole body weight) above the 2% level of dehydration; in consonance with the original reports of Ladell (3), little reliable effect of dehydration was noted until ~ this 2% dehydration level was achieved. In addition, the level at which an equilibrium of deep body temperature could be achieved (if at all), was increased by roughly 0.2°C for each percentage of dehydration above the 2% level. The extent to which these preliminary findings, obtained under a single work load and environmental condition, could be generalized to the entire problem of dehydration for the soldier in the field required further investigation. The approach applied in the present investigation was to study the acute phase of dehydration, which is more characteristic of a military operation in hot weather environments. Predictive modelling of the effects of dehydration for important physiological performance parameters, such as rectal temperature and heart rate, is to our knowledge non-existent. The purpose of these investigations was to derive predictive formulas for rectal temperature

and heart rate considering human performance of exercise in the heat.

Progress:

The technique for induction of dehydration was to determine initially the morning weight past urination of each of the 16 subjects for 4 - 5 days before the start of the study; the s established a "baseline" weight for each *individual subject*. Then, subjects were brought into the laboratory and acclimatized by walking in the heat at 1.34 m/s for two 50-minute periods separated by a 10-minute rest at 49°C, 20% r.h. Again during this period, individual daily waking body weights were determined over the 6 days of acclimatization. Subsequently, hydration was altered by having subjects report to the climatic chamber at 10 p.m. each evening and "rest" at 49°C, 20% r.h. while withholding, allowing or encouraging water intake, until the desired target dehydration was approached. At about 3 a.m. each morning, subjects were weighed and trans-ferred to a comfortable room to sleep. At 7:30 a.m. all men were weighed, state of dehydration estimated, and the men were then given a standard light breakfast, with fluids adjusted as appropriate to the target dehydration attempted for each individual.

Target hydration levels of 0, -3 and -5% of baseline were evaluated for rest or walking at 1.34 m/s, 0 and 5% grade, at: 54°C, 10% r.h.; 49°C, 20% r.h.; 35°C at 24, 48 and 72% r.h. and 25°C, 84% r.h. Exposure time totalled 110 min and for exercise involved two 50-minute walking periods with a 10 min intervening rest. Rectal temperature and mean weighted skin temperature were recorded continuously and heart rate checked periodically. The initial level of dehydration was maintained through the exposure by administration of water in amounts determined from the acclimatization days as adequate to maintain body hydration at the initial level. Subjects were evaluated only two days a week, allowing 48-hrs between exposures for full recovery of hydration and restful sleep. Thus, we obtained three levels of metabolic rate, and a wide variety of air temperatures and levels of humidity, at three levels of hydration.

From the analysis of data, it was possible to express the effect of dehydration as proportional to the final elevation in rectal temperature of hydrated subjects

exposed to similar conditions. The effects of the level of dehydration on rectal temperature are a faster rate of elevation and a higher final level when the duration of exposure is long enough. Previously published formulas for predicting rectal temperature (1) could be modified using an exponent containing a dimensionless constant and level of dehydration in percent. Predictive formulas for heart rate previously published (2) could also be modified to include a dimensionless constant while considering percent dehydration.

At rest, dehydration did not alter rectal temperature ($T_{re}$). Our empirically derived formulas (modified from J. Appl. Physiol. 32:812, 1972) for predicting at any time (t), and final $T_{re}$ ($T_{ref}$) and the time pattern of change during work ($T_{rew}$) and recovery ($T_{rer}$) are:

$$T_{ref} = 36.75 + 0.004(M-W_{ex}) + \left[(0.0128\ clo^{-1})(T_a-36) + 0.8e^{0.0047}(E_{req}-E_{max})\right] e^{0.01D}$$

$$\text{Work: } T_{ref} = T_{reo} + (T_{ref} - T_{reo})\left[1 - e^{-k}(t - t_d)(1 + 0.1D)\right]$$

$$\text{Rec: } T_{ret} = T_{rew} - (T_{rew} - T_{rer})\left[1 - e^{-00}(t - t_{drec})\, e^{-0.07D}\right]$$

where: D = % dehydration; op cit for other terms. A preliminary formula, predicting HR considering dehydration is:

$$I_{HR}\ (\text{Dehyd}) = 25 + (I_{HR} - 25)(1 + 0.06D)$$

Using this $I_{HR}$ for dehydration, final HR, and HR at time t, are computed as before (J. Appl. Physiol. 34:201, 1973).

Figure 1 displays $T_{re}$ responses with time for individual subjects at identical metabolic rates under similar environmental conditions, but different dehydration levels. The difference that exists between the responses for the individual subjects is obvious. In addtion, good agreement exists between the predicted response and the averaged measured $T_{re}$. It can be seen that the final $T_{re}$ for the first work and at the end of the exposure is higher as subjects are dehydrated.

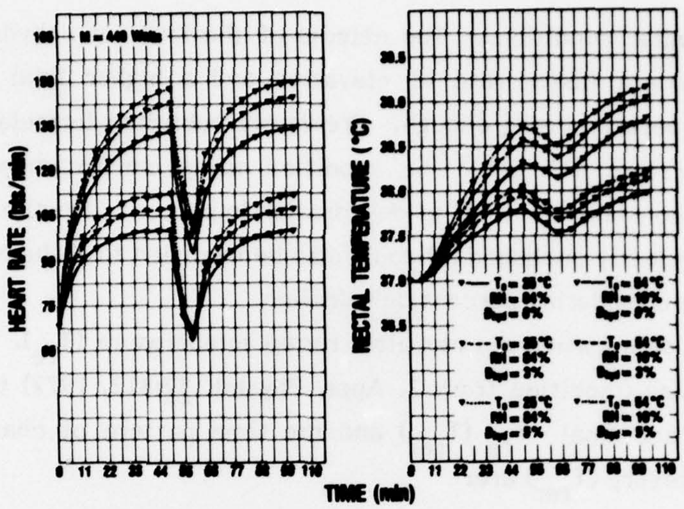

Figure 1. Comparison between predicted patterns (lines) and individual measured rectal temperatures (points) at identical metabolic rates (M), similar environmental conditions ($T_a$, r.h.), but different dehydration ($D_{hyd}$) levels.

Figure 2 presents the predicted responses for heart rate (HR) and $T_{re}$ at a metabolic rate of 440 watt and environmental conditions of 25°C, 84% r.h. and 54°C, 10% r.h. Dehydration levels were 0, 3 and 5%. Work consisted of two 50-minute periods with an intervening 10 minute rest. As the level of dehydration increased, the rate of rise and final level for HR and $T_{re}$ were increased. Obviously, the absolute values at 54°C, 10% r.h. are higher. At 54°C, 10% r.h., 5% dehydration is associated with about a 15 bt/min increase in HR and 0.4°C increase in $T_{re}$ as compared to 0% dehydration.

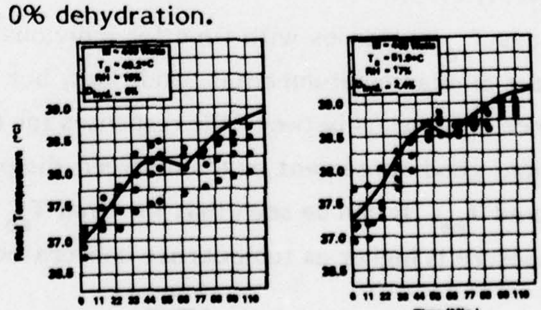

Figure 2. Predicted responses for heart rate and rectal temperature at a metabolic rate of 440 watt, environmental conditions at 25°C, 84% r.h. and 54°C, 10% r.h.; dehydration levels of 0, 3 and 5%. Work consisted of two 50-minute periods with an intervening 10 minute rest.

This prediction capability is to be added to our model predicting military performance capability and the occurrence of heat stress and/or heat casualties during military operations. Although it is most encouraging that the tentative coefficients developed originally on the basis of only one work and environmental level, fit the new data with only minor adjustment despite an interval of some two years between studies and an entirely different subject group an additional validation study of the coefficients derived from the current analyses will be required. The validation study will involve eight acclimatized subjects, three levels of dehydration (0, 3, 5%), two levels of physical work (300 and 500 Watt) and two environmental conditions ($35^{o}$, $49^{o}$C).

Presentations:

1. Pandolf, K. B., R. L. Burse, B. Givoni, R. G. Soule and R. F. Goldman. Effects of Dehydration on Predicted Rectal Temperature and Heart Rate During Work in the Heat. Medicine and Science in Sports, 9(1):51-52, 1977.

2. Pandolf, K. B., R. L. Burse, B. Givoni, R. G. Soule and R. F. Goldman. Predicting Rectal Temperature and Heart Rate Responses to Dehydration While Working in the Heat. XXVIIth International Congress of Physiological Sciences (Programme), pp. 12.21, 1977.

Publications:

None.

## LITERATURE CITED


1. Givoni, B. and R. F. Goldman. Predicting rectal temperature response to work, environment, and clothing. J. Appl. Physiol. 32(6):812-822, 1972.

2. Givoni, B and R. F. Goldman. Predicting heart rate response to work, environment and clothing. J. Appl. Physiol. 34(2):201-204, 1973.

3. Ladell, W. S. Effects on man of restricted water-supply. Committee on the Care of Shipwrecked Personnel. Medical Research Council, England 1943.

(83054)

# RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY

| 1. AGENCY ACCESSION* | 2. DATE OF SUMMARY* | REPORT CONTROL SYMBOL |
|---|---|---|
| DA OB 6139 | 77 10 01 | DD-DR&E(AR)636 |

| 3. DATE PREV SUM'RY | 4. KIND OF SUMMARY | 5. SUMMARY SCTY* | 6. WORK SECURITY* | 7. REGRADING* | 8a. DISB'N INSTR'N | 8b. SPECIFIC DATA-CONTRACTOR ACCESS | 9. LEVEL OF SUM |
|---|---|---|---|---|---|---|---|
| 77 09 02 | D. Change | U | U | NA | NL | [X] YES [ ] NO | A. WORK UNIT |

| 10. NO./CODES:* | PROGRAM ELEMENT | PROJECT NUMBER | TASK AREA NUMBER | WORK UNIT NUMBER |
|---|---|---|---|---|
| a. PRIMARY | 6.27.77.A | 3E762777A845 | 00 | 054 |
| b. CONTRIBUTING | | | | |
| c. XXXXXXX | CARDS 114f | | | |

11. TITLE (Precede with Security Classification Code)*

(U) Assessment of Cold Injury Susceptibility (22)

12. SCIENTIFIC AND TECHNOLOGICAL AREAS*

002600 Biology;003500 Clinical Medicine;005900Environmental Biology;012900 Physiology

| 13. START DATE | 14. ESTIMATED COMPLETION DATE | 15. FUNDING AGENCY | 16. PERFORMANCE METHOD |
|---|---|---|---|
| 76 10 | CONT | DA | C. In-House |

17. CONTRACT/GRANT

a. DATES/EFFECTIVE: EXPIRATION:

b. NUMBER:* NOT APPLICABLE

c. TYPE: d. AMOUNT:

e. KIND OF AWARD: f. CUM. AMT.

| 18. RESOURCES ESTIMATE | | a. PROFESSIONAL MAN YRS | b. FUNDS (In thousands) |
|---|---|---|---|
| FISCAL YEAR | PRECEDING 77 | 1.4 | 47 |
| | CURRENT 78 | 3.8 | 98.7 |

19. RESPONSIBLE DOD ORGANIZATION

NAME:* USA RSCH INST OF ENV MED

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RESPONSIBLE INDIVIDUAL

NAME: DANGERFIELD, HARRY G., M.D., COL, MC

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20. PERFORMING ORGANIZATION

NAME:* USA RSCH INST OF ENV MED

ADDRESS:* Natick, MA 01760

PRINCIPAL INVESTIGATOR (Furnish SSAN if U.S. Academic Institution)

NAME:* JACKSON, Ronald E., MAJ, MC

TELEPHONE: 955-2813

SOCIAL SECURITY ACCOUNT NUMBER:

ASSOCIATE INVESTIGATORS

NAME: HAMLET, Murray P., D.V.M.

NAME: 955-2865 DA

21. GENERAL USE

Foreign Intelligence Not Considered

22. KEYWORDS (Precede EACH with Security Classification Code)

(U) Cold Injury; (U) Cold Pressor Test; (U) CIVD; (U)Infrared Thermography

23. TECHNICAL OBJECTIVE,* 24. APPROACH, 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)

23. (U)Background characteristics of individuals suffering cold injury reveal differences in cold injury susceptibility in response to cold. Evidence to date suggests racial background, smoking habits, cold experience, cold injury, climatic origin, attitude and emotional characteristics represent important predictors. Cold hypersensitivity of these individuals may be detectible through simple temperature measurements either directly (thermocouples) or remotely (Infrared Thermography). From this research adequate medical screening and preventative training or instruction can be developed.

24. (U)A single hand cooling procedure will be used to define the onset of vasoconstriction and vasodilation in a normal and in a clinically identified abnormal population. Multi-point thermocouples and infrared thermography will be used. One hand will be cooled in air or water for a given duration to elicit vasoconstriction and CIVD. Subsequent temperature measurements and thermograms of both hands will differentiate centrally mediated vasoconstriction from local vasoconstriction.

25. (U) 76 10 - 77 09 Preliminary work on ten (10) human test subjects has been completed to evaluate rewarming response to a cold pressor test. Computer hardware has been acquired and development of software for analysis of thermographic temperature profiles is ongoing.

*Available to contractors upon originator's approval

| | |
|---|---|
| Program Element: | 6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE |
| Project: | 3E762777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance |
| Work Unit: | 054 Assessment of Cold Injury Susceptibility |
| Study Title: | Evaluation by Infrared Thermography of Susceptibility to Peripheral Local Cold Injury |
| Investigators: | Murray P. Hamlet, D.V.M., Joel J. Berberich, CPT, MSC, Ph.D. and John C. Donovan, CPT, VC |

Background:

Historically, military operations have been compromised as a result of cold injury. Analysis of previous wars has indicated that there may be soldiers who are more susceptible to cold injury (1,2). The fundamental objective of this study was to determine whether or not such individuals can be identified.

A screening procedure to identify soldiers who are more susceptible to cold injury should be practical. Such practicality entails three elements: it must be rapid, limited to the minimal population size, and non-invasive. These three elements will be considered sequentially. To evaluate individual susceptibility it is necessary first to have a standard method whereby moderate cold stress (exposure of an extremity either to cold air or cold water for a prolonged period, usually 15 minutes to several hours) can be simulated. If the assumption were made that the relative vascular reactivity to a moderate cold stress correlates with responses to a severe, injury-producing cold stress, the time of onset of vasodilation and the amount of heat flow to the extremity could be a measure of an individual's cold injury susceptibility. It is obvious that this method of testing is unsuitable for screening purpoese since it requires exposure to cold for long periods.

The cold pressor test, which has been used classically to measure vascular reactivity in relation to hypertension may be a desirable test for mass screening since it requires extremity immersion for only one minute. It is postulated that the mechanism involved in rewarming responses following prolonged cold exposure and brief ice water immersion may be similar. If so, the cold pressor test may be

suitable for mass screening for peripheral cold injury susceptibility. This will require experimental evaluation by comparing individual responses to the cold pressor test and prolonged cold exposure.

Whether or not the cold pressor test can be utilized in screening for cold injury susceptibility, it appears desirable to limit mass physiological screening to the minimal population size required to identify cold injury susceptible persons. Population size can be limited by identifying specific risk groups on the basis of background and psychological factors. Only these at risk groups would require individual physiological testing.

Finally, the measurement of the cold stress response of individuals should be done non-invasively and as rapidly as possible. Infrared thermography is such a rapid, non-invasive technique and may prove satisfactory for cold injury susceptible screening. Infrared thermography has been extensively employed in medical applications. The present state of the art of infrared thermography is the AGA Thermovision system (AGA, Aktiebolag) (3,4).

In summary, these three elements must be considered in planning a program to define cold injury susceptibility: rapid testing, non-invasive testing, and testing

## Progress:

Efforts to date have centered on the development of a rapid, efficient system to acquire data from the AGA infrared thermography system. To accomplish this, peripheral devices have been acquired to permit interfacing with a PDP-11 minicomputer via a controller unit and video memory disc. Initial software development is now ongoing to permit analysis of thermographic temperature profiles by computer.

At the same time, preliminary investigations have been conducted on 10 human subjects to evaluate rewarming responses to a cold pressor test. Data has been acquired from sequential color photographs of thermography profiles. This data acquisition has been useful in defining an appropriate cold pressor test, but rewarming data is clearly inadequate since dynamic changes in blood flow are not recorded. Formal investigation will commence upon completion of computer interfacing and software development for analysis of thermographic temperature profiles.

Presentations:

None

Publications:

None

## LITERATURE CITED


1. Whayne, T. F. and M. E. DeBakey. Cold Injury, Ground Type, in World War II. Washington, DC: Department of the Army, 570 p., 1958.

2. Orr, K. D. and Associates. Cold Injury: Korea 1951-52; Summary of Activities, Cold Injury Research Team Korea 1951-52. Fort Knox, Kentucky: Army Medical Research Laboratory, 1058 p., 1953.

3. Borg, S. B. and L. E. Mallner. AGA thermovision, thermography with real-time presentation. In: Medical Thermography, ed. K. Atsumi, pp. 76-96, Tokyo: University of Tokyo Press, 1973.

4. Meyfarth, W. H. Thermographic temperature measurement. Eng. Dig. 18, 1973.

(83055)

| RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY | 1. AGENCY ACCESSION* | 2. DATE OF SUMMARY* | REPORT CONTROL SYMBOL |
|---|---|---|---|
| | DA OC 6121 | 77 10 01 | DD-DR&E(AR)636 |

| 3. DATE PREV SUM'RY | 4. KIND OF SUMMARY | 5. SUMMARY SCTY* | 6. WORK SECURITY* | 7. REGRADING* | 8a. DISB'N INSTR'N | 8b. SPECIFIC DATA-CONTRACTOR ACCESS | 9. LEVEL OF SUM |
|---|---|---|---|---|---|---|---|
| NA | D.Change | U | U | NA | NL | [X] YES [ ] NO | A. WORK UNIT |

| 10. NO./CODES:* | PROGRAM ELEMENT | PROJECT NUMBER | TASK AREA NUMBER | WORK UNIT NUMBER |
|---|---|---|---|---|
| a. PRIMARY | 6.27.77.A | 3E762777A845 | 00 | 055 |
| b. CONTRIBUTING | | | | |
| c. XXXXXXX | CARDS 114f | | | |

11. TITLE (Precede with Security Classification Code)* Fire Direction Center (FDC) Team Health and Efficiency Under Environmental and Situational Stress in Simulated Combat Operations

12. SCIENTIFIC AND TECHNOLOGICAL AREAS* 013400 Psychology; 016200 Stress Physiology; 005900 Environmental Biology; 007900 Occupational Mèdicine; 002300 Biochemistry

| 13. START DATE | 14. ESTIMATED COMPLETION DATE | 15. FUNDING AGENCY | 16. PERFORMANCE METHOD |
|---|---|---|---|
| 76 10 | CONT | DA | C. In-House |

17. CONTRACT/GRANT
a. DATES/EFFECTIVE: NOT APPLICABLE EXPIRATION:
b. NUMBER:*
c. TYPE: d. AMOUNT:
e. KIND OF AWARD: f. CUM. AMT.

| 18. RESOURCES ESTIMATE | | a. PROFESSIONAL MAN YRS | b. FUNDS (In thousands) |
|---|---|---|---|
| FISCAL YEAR | PRECEDING 77 | 8.3 | 276.3 |
| | CURRENT | | |

19. RESPONSIBLE DOD ORGANIZATION
NAME:* USA RSCH INST OF ENV MED
ADDRESS:* Natick, MA 01760
RESPONSIBLE INDIVIDUAL
NAME: DANGERFIELD, HARRY G., M.D., COL, MC
TELEPHONE: 955-2811

20. PERFORMING ORGANIZATION
NAME:* USA RSCH INST OF ENV MED
ADDRESS:* Natick, MA 01760
PRINCIPAL INVESTIGATOR (Furnish SSAN if U.S. Academic Institution)
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TELEPHONE: 955-2822
SOCIAL SECURITY ACCOUNT NUMBER:
ASSOCIATE INVESTIGATORS
NAME: BANDERET, Louis E., Ph.D.
NAME: DA

21. GENERAL USE
Foreign Intelligence Not Considered

22. KEYWORDS (Precede EACH with Security Classification Code) (U)Team Performance; (U)Environmental Stress; (U)Sustained or continuous operations; (U)Fatigue,Mental; (U)Psychomotor & Cognitive Function; (U)Motivation

23. TECHNICAL OBJECTIVE.* 24. APPROACH, 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)

23. (U)Opposing threat doctrine may require that the Army deploy to harsh climates to fight for five or more days without rest. This work unit quantifies, correlates and describes in a military context the interaction of: 1) harsh climatic conditions; 2) common military stressors such as mission demands, noise, crowded work space, and sustained operations with sleep disruption or deprivation; 3) the acute physiological, biochemical, medical and psychosocial status of functioning team members; 4) individual and team operational effectiveness over time.

24. (U)FDC teams from line Field Artillery units are tested for extended periods in naturalistic combat simulations as a "model" command/control and communications system. Multi-disciplinary data collection and correlation is done to assess the operational as well as medical cost to teams functioning under stress, determine rates of recovery following exposure, identify predictors of operational degradation, establish mechanisms of action, and test prophylactic or therapeutic interventions.

25. (U)76 10 - 77 09 Four 82d ABN Div teams performed sustained operations at USARIEM for either, 1) two 38h matched scenarios separated by a 34 h rest, 2) the same scenario as a single operation until voluntary termination at 48h and 45h. Team system output showed measurable deterioration; greatest, a) for secondary tasks (target pre-planning), b) in the less experienced team, c) prior to voluntary termination. Primary task accuracy (fire missions) was generally maintained with variable slowing of response. Physical fitness testing, urinary 17 OHCS, and psychological tests suggested impaired recovery following repeated 38h sustained ops in one team. The tri-institute Project Team (USARIEM, WRAIR, NHRC) is analyzing system integrity measures, individual performance, mood and symptoms, EKG, activity, sleep EEG, cerebral dominance, team social interaction, etc. Use of the FDC team model at USARIEM is being considered to test effects of heat stress, perhaps including CBR uniform.

*Available to contractors upon originator's approval.



DD FORM 1 MAR 68 1498 PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE. DD FORMS 1498A, 1 NOV 65 AND 1498-1, 1 MAR 68 (FOR ARMY USE) ARE OBSOLETE.

Program Element: 6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE

Project: 3E762777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance

Work Unit: 055 Fire Direction Center (FDC) Team Health and Efficiency Under Environmental and Situational Stress in Simulated Combat Operations

Study Title: Fire Direction Center (FDC) Team Efficiency and Well-being in Simulated Sustained Operations

Investigators: James W. Stokes, M.D., LTC, MC, Louis E. Banderet, Ph.D., Ralph Francesconi, Ph.D., Edward J. McCarroll, MAJ, MSC, and Dennis M. Kowal, Ph.D., CPT, MSC

Background:

Should US Forces be deployed in defensive, sustained operations against numerically superior forces, there is a requirement to have defined the physiological and psychological costs imposed upon personnel by continuous combat and environmental stresses (1). It was postulated that such complex problems could be studied in a laboratory simulation which would use actual Army teams performing their normal functions, yet permit control and replication of environmental and situational conditions and measurement and correlation of mission effectiveness, behavior and biological processes. Field Artillery Fire Direction Center teams (FDC) are well suited for such a laboratory simulation for the following reasons: 1) FDCs are common and critical to successful ground combat operations; 2) FDC teams are located immediately behind the FEBA in either a general purpose tent or command post vehicle and, hence, are exposed to most extant stresses; 3) FDC performance includes tasks common to other command control and communications elements, while their mission output provides quantifiable measures of both individual and team performance and 4) detailed scenarios can be generated to provide face-validity and calibrated performance demands.

Preliminary studies of FDC teams were conducted at USARIEM in 1974 and have been reported (2,3). For the 1977 studies described below, the scenario was updated with the assistance of the US Army Field Artillery School (USAFAS) and 82d Airborne Division to reflect current emphasis on continuous combat and on preplanning of targets to achieve speed and accuracy of artillery fire to suppress enemy weapons. In addition to the measures of team and individual performance evaluated, other parameters were included: 1) the effects of sleep deprivation on work capacity, 2) an estimation of physiological cost by determining biochemical indices of neuroendocrine function and 3) an assessment of the psychological effects experienced by individual members of the FDC.

Previous reports of the of sleep deprivation upon physical work capacity have failed to describe major changes. The Harvard Step Test Index, a measure of aerobic fitness was reported to remain stable throughout 120 hours of sleep deprivation but then demonstrated significantly reduced fitness following post-deprivation sleep (4). Increased oxygen uptake at rest (5) and during submaximal work (4), increased serum pyruvate (6) and other biochemical changes have been interpreted as reflecting a metabolic shift from carbohydrate to fat utilization. It has been hypothesized that the neuroendocrine response to physical and/or psychological stress is in most instances triggered by perception of uncertainty or threat (7). Novel situations produce this response but psychological defense mechanisms may attenuate it in the presence of obvious danger or physiological stress; results from the preliminary FDC studies were consistent with this observation (3). In the military context, this phenomenon has been demonstrated by measuring urinary 17-hydroxycorticosteroid (17-OHCS) (8,9). The latter reference suggests that 17-OHCS excretion may actually decrease when highly-trained troops faced with danger perform routine tasks. It has also been reported that the catecholamines, epinephrine (EP) and norepinephrine (NE), and their metabolites typically increase during stress (7). Total urinary catecholamines generally have been related to arousal levels.

**Progress:**

Four five-man FDC teams from two Field Artillery battalions of the 82d Airborne Division were tested. Teams 1, 2, and 3 were composed of highly trained

personnel. Although Team 4 was led by an experienced Fire Direction Officer (FDO) and NCOIC Computer (COM), the radio-telephone operator (RTO) and horizontal and vertical chart operator (HCO and VCO, respectively) were relatively inexperienced. All subjects were healthy males (ages 18-24) and fully informed volunteers. TO&E manual FDC equipment was assembled in a tent inside a 20 x 9 x 8 ft. hypobaric chamber. Ambient temperature was maintained between 68 and 75$^{O}$F and relative humidity between 35 and 50%. Lighting conditions were superior to those in the field so that continuous videotaping could be accomplished. The three radionets featured simulated static and non-relevant as well as mission-related message traffic, and a sound effects system provided intermittent, moderately loud sounds of howitzer blasts. No requirements were placed on the volunteers to move the FDC or dig emplacements. Each subject was equipped with a microphone and radio transmitter to facilitate voice recording; all internal and external communication was recorded with a time signal on an audio recorder and on videotape. Team interactions and behavior were scored by observers via a one-way mirror and video monitors. In addition, each subject was instrumented with a Medilog cassette tape recorder, wrist actograph and ECG electrodes and, in some instances, EEG electrodes. During the test, supplemented C-rations and hot coffee were provided. Between tests, subjects were housed in a dormitory; sleep EEG, EOG and ECG were recorded on these nights.

Investigators from the Walter Reed Army Institute of Research (WRAIR) Division of Neuropsychiatry, (Departments of Military Psychiatry, Psychophysiology, and Neurosciences,) and from the Naval Health Research Center (NHRC) Psychophysiology Division, collaborated in the design and conduct of this study. Table 1 details the schedule of tests and procedures performed. Only data obtained by USARIEM investigators will be presented in this report. Two experimental designs were employed. These are illustrated in Figure 1. Each team received an initial 5-hr orientation followed by three 8-hr days of operations at a level of effort comparable to that required during the subsequent trials in order to minimize subsequent practice effects. Teams 1 and 4 then underwent a single sustained operations test which they were told could continue for 86 hrs. Teams 2 and 3 participated in two 38-hr sustained operations separated by a 34-hr rest interval.

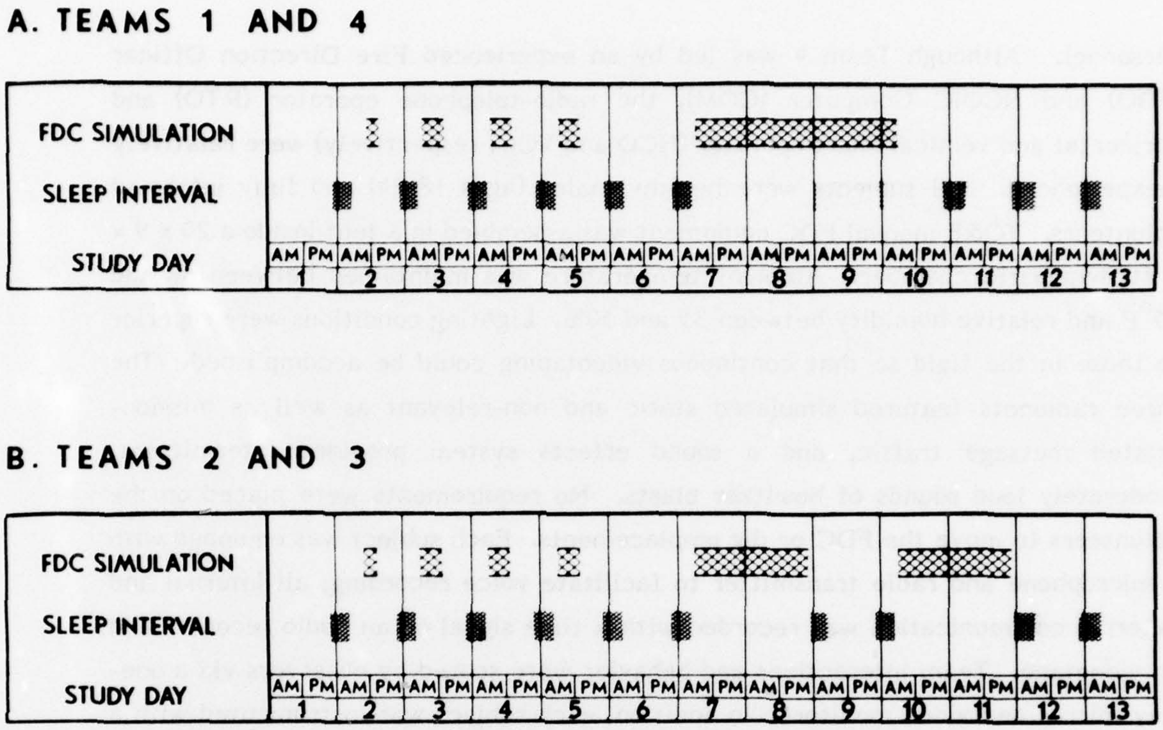


**FIGURE 1. EXPERIMENTAL DESIGNS**

The scenario encompassed a tactical battle played on 1:50,000 scale maps and followed current doctrine for a light infantry task force advancing against a well-equipped screening force. Calls for fire, encoded target lists, position reports and other administrative messages sent to the FDC teams by role players determined the work intensity. At 6-hr intervals, approximately 48 minutes were spent in administrative activities, e.g., completion of self-report questionnaires, electrode maintenance, etc. These periods corresponded to times required for the Field Artillery battery to make a tactical move. Mission input (task demands) during the remainder of the 6-hr was matched for difficulty and pace with all other 6-hr to permit comparison of performance and non-task indices. Two general types of mission input were among the events included in the scenario: 1) new missions or

primary tasks, and 2) preplanned targets or secondary tasks. The former were calls for fire by forward observers on unpreplanned grid coordinates, plus subsequent adjustments from simulated initial rounds. To respond to these calls, immediate computation and output took precedence. Speed of response was critical and the team was prompted by the role players if it was too slow. The latter, or preplanned targets, were received periodically by the FDC via radio in number and cipher code. Data for these were to be processed and available on-call. At intervals certain preplanned targets were designated priority to the team so it could alert simulated guns. Periodic updating of these preplanned data was expected. In contrast to new mission, there was no prompting of a team and between 25 and 50% of these preplanned targets were never called for. However, the experimental context, like current artillery doctrine, stressed the importance of target preplanning, and quick response was demanded when targets were called for.

Performance of each team in terms of mission input (new missions and preplanned targets) was evaluated for accuracy (concordance between the FDC team's firing data output and the correct solution computed by the USAFAS) and for speed (latency - the time between mission input and team data output). Accuracy and speed were independently rescored from the audiotape. Any discrepancies in the independent evaluations were resolved by further examining the audiotape and its time signal. For this interim report, criteria for good accuracy and speed were established in order that a given team's performance could be compared over time rather than to another team (Table 2). A single criterion was selected for accuracy but would not suffice for speed or latency. Instead, these latter criteria were based on 75% of that rate achieved by a team either during the last 6-hr of training or the first 6-hr of testing, whichever was faster. All teams were also judged by common standards for unacceptable performance.

TABLE I SCHEDULE OF TESTING DURING FDC TEAM STUDY

| TEST | TEAM | DAY(D), NIGHT(N), TIME(HR) | INVESTIGATOR |
|---|---|---|---|
| **FDC Performance Assessment** | | | |
| a) orientation | 1,2,3,4 | D2 (1100 to 1600) | L. Banderet[1] |
| b) training | 1,2,3,4 | D3,4,5 (0700 to 1500) | J. Stokes[1] |
| c) test | 1 | D7 (0700) to D9 (0700) | |
| | 4 | D7 (0700) to D8 (2100) | J. Schrot[2B] |
| | 2,3 | D7 (0700) to D8 (2100) | |
| | 2,3 | D10 (0700) to D11 (2100) | |
| **Physical Work Capacity** | | | |
| Max $VO_2$ treadmill | 1,2 | D2 (0900) to D3 (1500) | D. Kowal[1] |
| Submaximal $VO_2$ | | D4 (1500), D9 (0800), D10 (1000) | W. Daniels[1] |
| (Astrand bicycle) | 2 | D4 (1500), D8 (2100, D9 (1000) | |
| | | D11 (2100), D12 (1000) | |
| **Urinary Creatinine, 17-OHCS, Total Catecholamines** | | | |
| Control | 1 | ea 6 h; D3 (1200) to D5 (1200) | R. Francesconi[1] |
| | 2,4 | ea 6 h; D3 (0600) to D5 (0600) | |
| Experimental | 1,4 | ea 6 h during sustained ops | |
| | 2 | ea 6 h during sustained ops plus last 3 h + 12 h sleep | |
| **Psychological Evaluation** | | | |
| General Health Questionnaire | 1,4 | D3 (1900), D10 (1500) | J. McCarroll[1] |
| & Health Opinion Survey | 2,3 | D3 (1900), D13 (0900) | |
| Cornell Medical Index | 1,2,3,4 | approx ea 0600, 1200, 1800 and bedtime during baseline and ea 0600, 1200, 1800, 2400 during simulations | S. Genser[2B] G. Belenky[2C] |
| Cerebral Assymetry Testing | 1,2,3,4 | ea 0600, 1200, 1800, and 2400 during simulations | |
| with EEG | 1,2,3,4 | D6 (0800-1200) | |
| **Behavioral Observation** | 1,2,3,4 | throughout sustained mission simulations | R. Schneider[2A] G. Bishop[2A] D. Marlowe[2A] K. Graeber[2B] |
| **ECG and Actograph** | 1,2,3,4 | throughout mission simulations | R. Jennings[2B] F. Hegge[2B] |
| **Sleep EEG, EOG, ECG** | | | |
| Baseline | 1*,2*,3,4 | N1,2,3,4,5,6 | P. Naitoh[3] |
| Recovery | 1*,4 | D9,N9,10,11 | |
| | 2*,3 | N8,9,11,12,13 | |
| **Waking EEG** | 1*,4 | throughout mission simulations | |
| **Serum Creatine Phosphokinase+** | 1,4 | D7 (0600) | D. McFarling[2C] |

*COM only

[1]=USARIEM

[2]=WRAIR [A]=Dept. Military Psychiatry [B]=Dept. Military Psychophysiology [C]=Dept. Military Neurosciences

[3]=NHRC

TABLE 2. Criteria of Team Performance Levels

| Measure | Team | Good | Unacceptable |
|---|---|---|---|
| Accuracy (new mission & preplanned) | 1,2,3,4 | 3mil* | 15 mil |
| Speed new mission (adjustments) | 1 | ≤ 30 sec | ≥60 sec |
| | 2 | ≤ 28 sec | ≥60 sec |
| | 3 | ≤ 29 sec | ≥60 sec |
| | 4 | ≤ 40 sec | ≥60 sec |
| Latency of Preplanning | 1,3 | ≤ 34 min | >60 min |
| | 2 | ≤ 19 min | ≥60 min |
| | 4 | ≤ 40 min | ≥60 min |
| Latency of Priority Preplanning | 1 | ≤ 72 sec | ≥ 5 min |
| | 2 | ≤ 60 sec | ≥ 5 min |
| | 3 | ≤ 36 sec | ≥ 5 min |
| | 4 | ≤ 3 min | ≥ 5 min |

*The mil ($\cancel{m}$) is the unit of angular measure used in artillery firing data; 6400 $\cancel{m}$ = 360°. 3 mil is the approximate tolerance between two, independently performed manual computations if no error is committed at any step.

Team output performance, in terms of the accuracy and speed with which task demands were accomplished, was calculated:

$$\text{percent task demand (\% TD)} = \frac{\text{Number of observed responses meeting criterion each 6-hr}}{\text{Number of times responses were called for each 6-hr}} \times 100$$

Performance results for each team, i.e., % TD for good and for inadequate accuracy of firing data, computation speed, and latency of preplanning and priority preplanning, are depicted in Figures 2-5.

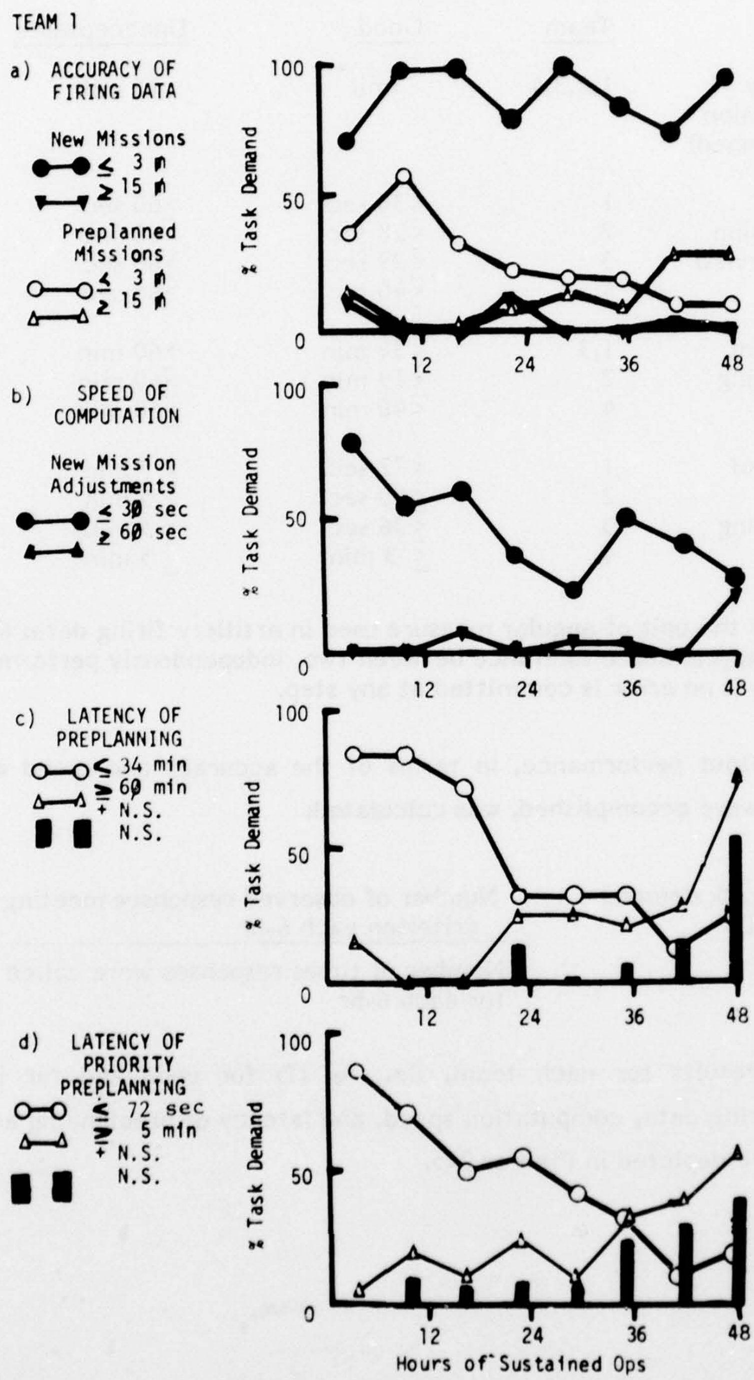


FIGURE 2: TEAM 1 performance output over time; % within criterion for good and for unacceptable

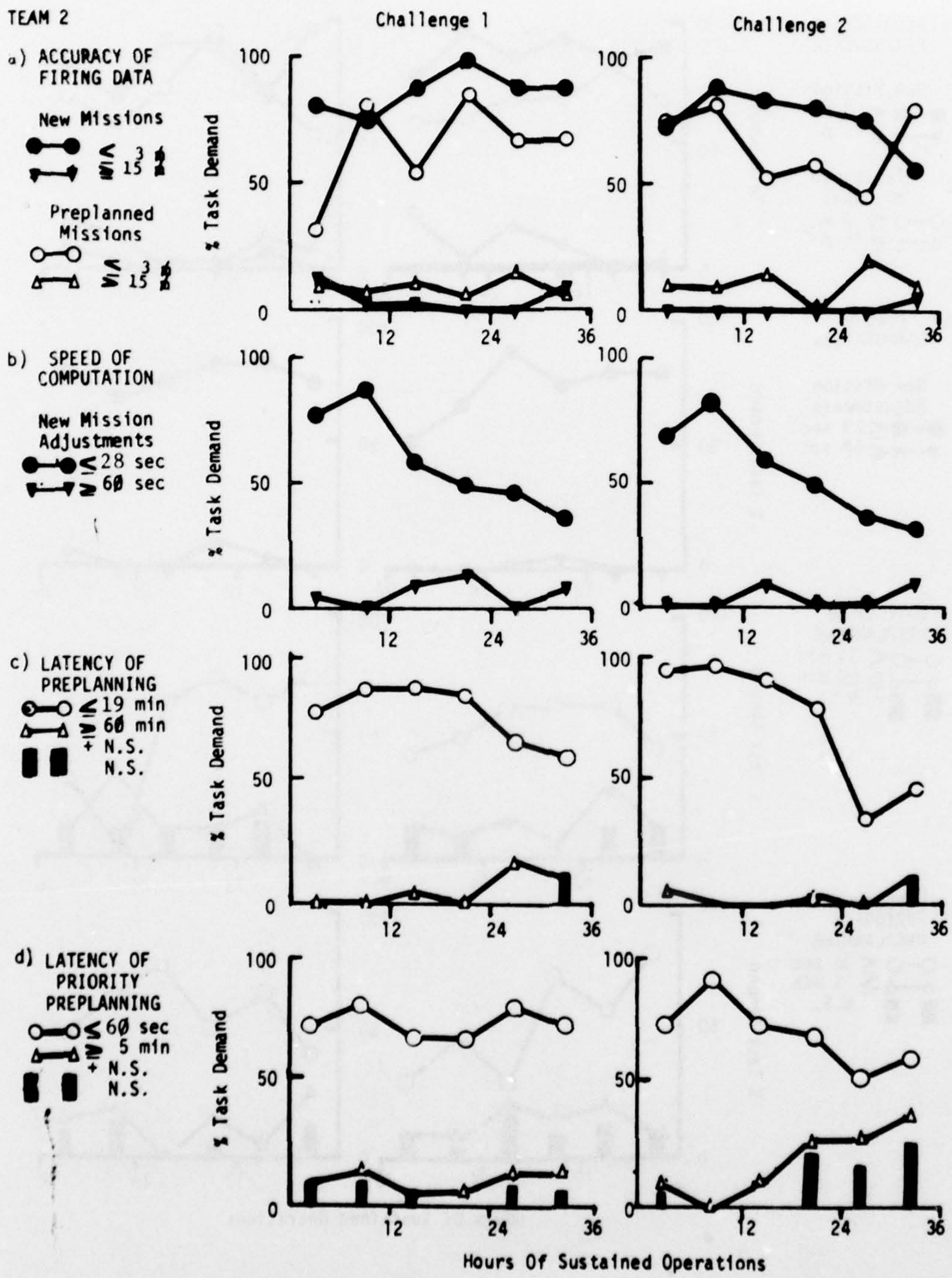


FIGURE 3: TEAM 2 performance output over time; % within criterion for good and for unacceptable

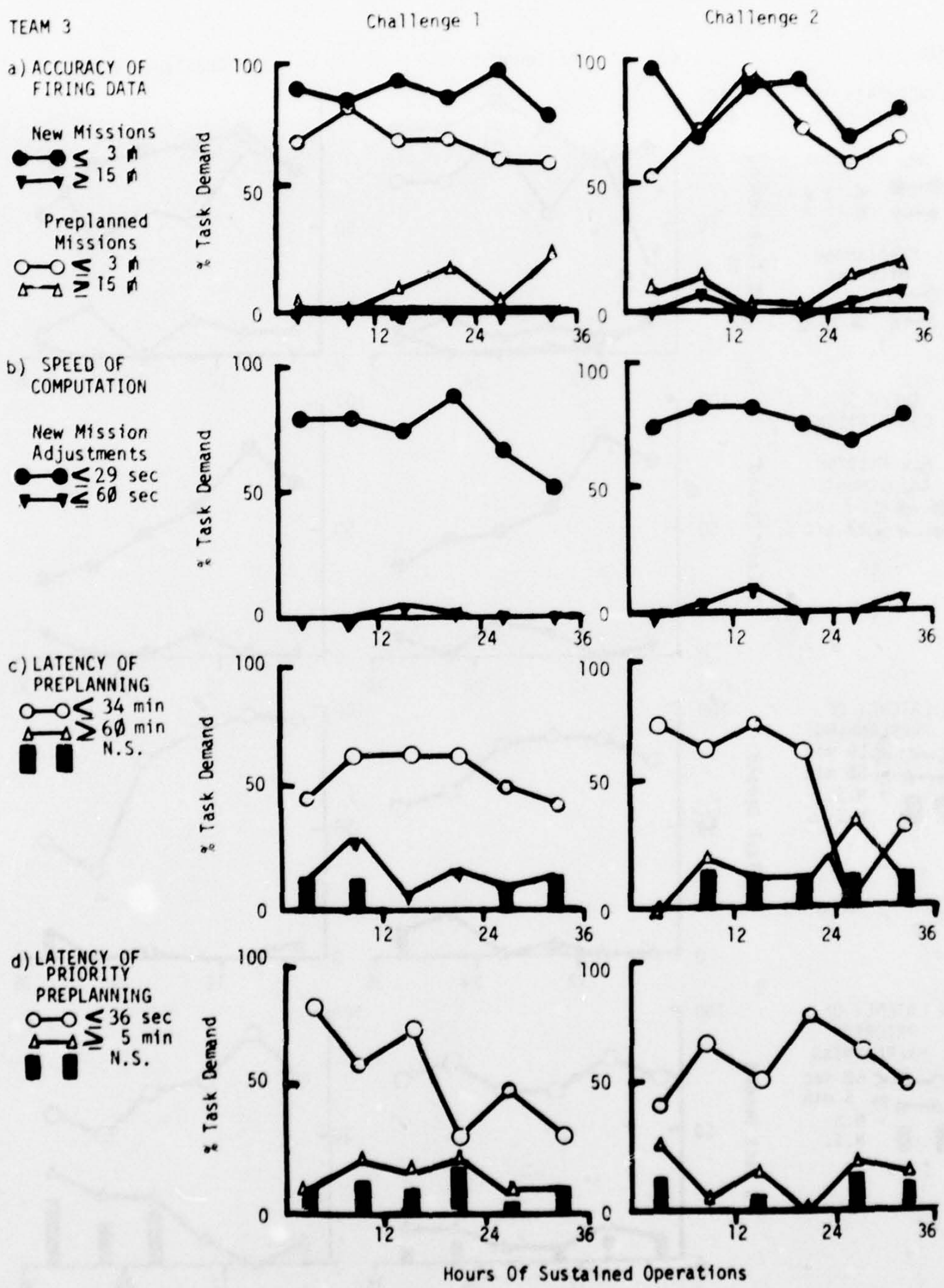


FIGURE 4: TEAM 3 performance output over time; % within criterion for good and for unacceptable

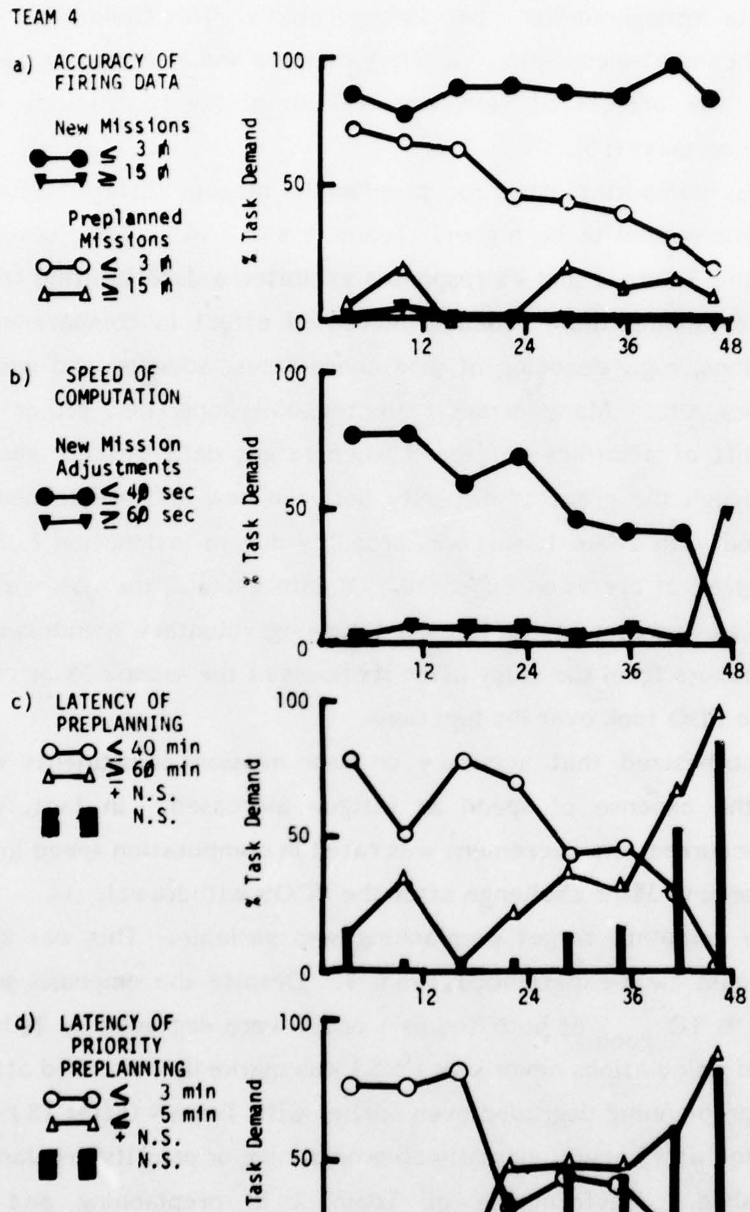


**FIGURE 5:** *TEAM 4 performance output over time; % within criterion for good and for unacceptable*

It can be seen that each team maintained high levels of accuracy in new mission firing data throughout the scheduled operations. This finding corroborated the prediction of combat-experienced artillery officers and also was in consonance with reports of the effects of sleep-deprivation on highly trained, stimulus-initiated, self-paced tasks (10).

Accuracy in computing data for preplanned targets differed in that the baseline error rate tended to be higher. Teams 2 and 3 displayed fluctuations in their responses and Teams 1 and 4's responses exhibited a deteriorating trend over time. These preplanning tasks required increased effort in comparison to new mission calculations, e.g., decoding of grid coordinates, addition and updating of correction factors, etc. Many errors reflected omissions, i.e., either lapse or deliberate tradeoff of accuracy for speed when target data was not ready when called for. Although the greatest disparity between new and preplanned mission accuracy occurred with Team 1, this was probably due to instruction failure with regard to the degree of precision expected. Of interest was the observation that this difference was decreased with Team 3 following voluntary withdrawal of one of the chart operators from the study after six hours of the second 38-hr challenge, at which time the FDO took over his functions.

It was hypothesized that accuracy on new mission adjustments would be maintained at the expense of speed as fatigue increased. In fact, with one exception, this occurred; no decrement was rated in computation speed in Team 3, even during the second 38-hr challenge after the VCO's withdrawal.

Latency to complete target preplanning was variable. This was especially marked in the least field-experienced Team 4. Despite the emphasis placed on preplanning, the % $TD_{good}$ of both Teams 1 and 4 were degraded by 24 hours and the percentage of calculations never sent (N.S.) was markedly increased after 36-42 hours. Priority preplanning degraded even earlier with Team 4 (after 18 hours) and when it terminated at 45 hours, virtually no preplanning or priority preplanning was being accomplished. Performance of Team 2 in preplanning and priority preplanning was stable during the first 38-hr trial, although a slight decrease in good and increase in unacceptable responses occurred during the last 12 hours. A larger decrement in good performance occurred at the same point during the second interval but was unaccompanied by an increase in unacceptable responses.

Evaluation of Team 3 is confounded by their being short one man in the 2d challenge; it can be seen that priority preplanning improved temporarily following their reorganization, but overall planning could not be sustained as well as in the first challenge.

In addition to performance measures of accuracy and speed, the impact of prolonged operations upon physical work capacity and neuroendocrine and psychological responses were evaluated. Aerobic fitness was assessed by means of the Åstrand bicycle submaximal work test (11). Oxygen uptake in ml/kg·min ($\dot{V}O_{2\ submax}$) and heart rates ($HR_{submax}$) were determined in Team 1 during the initial week of familiarization testing (control), at the conclusion of the 48-hr test and again after 24-hr rest. For Team 2, individuals were tested during control, at the conclusion of both 38-hr tests and also after approximately 13-hr rest following each challenge. Total urinary output was collected at 6-hr intervals, the volumes recorded, creatinine analyzed and an aliquot frozen immediately for analysis of 17-OHCS and catecholamine concentrations. For the control sample, total urinary output was collected over a 48-hr period during the initial week of active work-rest cycling after novelty effects were assumed to be partially attenuated. Six-hr collections were resumed at the beginning of each period of sustained operation. For Team 1 and 4 members, collection terminated at the end of the single test. For Team 2 urines were collected during both 38-hr tests and over the first night of sleep following each; data reported below cover only the first 36-hr of each test and an equivalent 36-hr during control. Responses to these parameters by individual members of Teams 1 and 2 are shown in Tables 3 and 4, respectively.

Three Team 1 members had increased $\dot{V}O_{2\ submax}$ at the end of the 48-hr operation, and 4 post-rest. Heart rates were also increased; the team mean was significantly increased at both experimental times. With the exception of the COM, Team 1 members had increased urinary 17-OHCS and all had elevated catecholamine excretion.

All five members of Team 2 demonstrated increased $\dot{V}O_{2\ submax}$ and $HR_{submax}$ by the end of the second 38-hr test and following the subsequent night's sleep; these changes were highly significant for both $\dot{V}O_2$ HR ($P = .001$). The

TABLE 3

Physical Work Capacity, Neuroendocrine and Psychological Symptom Measures by Individual FDC Team Members, Team 1

| PARAMETER TEST | SUBJECT | CONDITION: CONTROL | CONDITION: 48 HR TEST | CONDITION: REST |
|---|---|---|---|---|
| Submaximal work $VO_2$ (ml/kg·min) | FDO | 24.2 | 20.5 | 24.0 |
| | COM | 30.9 | 29.5 | 33.7 |
| | RTO | 25.3 | 32.2 | 23.3 |
| | VCO | 32.7 | 34.9 | 36.7 |
| | HCO | 29.4 | 31.1 | 37.7 |
| | $\bar{X} \pm$S.E. | 28.5±1.6 | 29.6±2.5 | 32.8±2.4 |
| Heart Rate (Beats/min) | FDO | 148 | 147 | 150 |
| | COM | 143 | 145 | 147 |
| | RTO | 150 | 157 | 160 |
| | VCO | 150 | 168 | 166 |
| | HCO | 135 | 160 | 168 |
| | $\bar{X} \pm$S.E. | 145±2.9 | 155±4.3[a] | 158±4.2[a] |
| Urinary 17-OHCS (Total mg/48 hr) | FDO | 12.7 | 15.8 | |
| | COM | 14.2 | 13.7 | |
| | RTO | 13.7 | 21.2 | |
| | VCO | 10.2 | 12.2 | |
| | HCO | | | |
| | $\bar{X} \pm$S.E. | 12.7±0.9 | 15.7±2.0 | |
| Urinary Catecholamines (Total µ/48 hr) | FDO | 353 | 365 | |
| | COM | 179 | 202 | |
| | RTO | 246 | 307 | |
| | VCO | 192 | 267 | |
| | HCO | | | |
| | $\bar{X} \pm$S.E. | 243±39.6 | 285±34.3 | |
| General Health Questionnaire Score | FDO | 27 | | 39 |
| | COM | 59 | | 32 |
| | RTO | 31 | | 23 |
| | VCO | 79 | | 25 |
| | HCO | 46 | | 38 |
| | $\bar{X} \pm$S.E. | 48.4±9.5 | | 31.4±3.3 |

a. P=<.05

## TABLE 4

Physical Work Capacity, Neuroendocrine and Psychological Symptom Measures by Individual FDC Team Members, Team 2

| PARAMETER TEST | SUBJECT | CONDITION CONTROL | TEST 1 | REST 1 | TEST 2 | REST 2 |
|---|---|---|---|---|---|---|
| Submaximal work $VO_2$ (ml/kg·min) | FDO | 34.9 | 37.2 | 32.6 | 41.4 | 44.6 |
| | COM | 39.3[a] | 42.6 | 32.0 | 41.5 | 47.9 |
| | RTO | 38.6 | 38.4 | 38.2 | 45.5 | 44.6 |
| | VCO | 38.2 | 32.2 | 36.3 | 37.1 | 44.2 |
| | HCO | 30.0 | 30.6 | 25.9 | 30.2 | 34.3 |
| | $\bar{X}\pm$S.E. | $36.2\pm1.7$ | $36.2\pm2.2$ | $33.0\pm2.1$ | $39.1\pm2.6$ | $43.1\pm2.3$[b] |
| Heart Rate (Beats/min) | FDO | 120 | 115 | 110 | 135 | 137 |
| | COM | 165[a] | 170 | 168 | 180 | 181 |
| | RTO | 157 | 169 | 180 | 181 | 183 |
| | VCO | 164 | 152 | 170 | 174 | 170 |
| | HCO | 153 | 156 | 160 | 168 | 175 |
| | $\bar{X}\pm$S.E. | $152\pm8.4$ | $152\pm10.0$ | $158\pm12.3$ | $168\pm8.5$[b] | $169\pm8.4$[b] |
| Urinary 17-OHCS (Total mg/36h) | FDO | 10.4 | 7.4 | | 6.0 | |
| | COM | 8.9 | 12.0 | | 7.2 | |
| | RTO | 11.0 | 7.0 | | 2.5 | |
| | VCO | --- | --- | | --- | |
| | HCO | 7.5 | 10.6 | | 10.8 | |
| | $\bar{X}\pm$S.E. | $9.5\pm0.8$ | $9.3\pm1.2$ | | $6.6\pm1.7$ | |
| Urinary Catecholamines (Total µ/36h) | FDO | 153 | 116 | | 125 | |
| | COM | 115 | 181 | | 196 | |
| | RTO | 121 | 104 | | 112 | |
| | VCO | --- | --- | | --- | |
| | HCO | 80 | 87 | | 84 | |
| | $\bar{X}\pm$S.E. | $117\pm15$ | $122\pm20.6$ | | $129\pm23.8$ | |
| General Health Questionnaire Score | FDO | 53 | | | | 46 |
| | COM | 23 | | | | 31 |
| | RTO | 33 | | | | 58 |
| | VCO | 30 | | | | 55 |
| | HCO | 49 | | | | 30 |
| | $\bar{X}\pm$S.E. | $37.6\pm5.7$ | | | | $44\pm5.9$ |

a. Calculated for missing data
b. P = <.001, 2 way analysis of variance, subject x time

effect was greatest in the three individuals who had had the most continuous tasks, FDO, RTO, and COM, the latter especially after post-test sleep (Rest 2). Excretion of urinary 17-OHCS and catecholamines was variable in Team 2 members. The FDO consistently excreted less 17-OHCS (-29% and -42%) during the tests than during the control period. The RTO showed even greater decreases (-36% and -77%). Catecholamine excretion was also decreased in both (FDO: -24% and -18%; RTO: -14% and -7%). The COM had increased 17-OHCS excretion throughout Test 1 (+35%), but decreased (-19%) during Test 2. His catecholamine excretion was elevated throughout both Tests (+57% and +70%). In view of the $\dot{V}O_2$ and $HR_{submax}$ changes in this individual, it is interesting that these biochemical trends progressed markedly during the night of sleep following the last test, with 17-OHCS -65% and catecholamones +213% compared with the last 12-hr of rest and sleep during the 48 hr control collection (data not shown in the Table). The HCO had elevated urinary 17-OHCS during both tests with negligeable change in total catecholamines.

When 17-OHCS values were adjusted for a standard body weight, all subjects had lower baseline urinary excretion, in comparison to the average of 3.5 mg/24 hr excreted by a population of basic trainees (12). These low values were similar to those reported from combat-experienced troops in Vietnam (8).

Psychological responses experienced by the individuals of the 4 FDC teams were also evaluated. Two standard psychiatric epidemiologic assessments were utilized: 1) the General Health Questionnaire (GHQ) (13), and 2) the Health Opinion Survey (HOS) (14). Both questionnaires were administered during the familiarization period (control) and approximately 36-hr after the conclusion of the simulated operation(s). The GHQ consists of 60 items covering symptoms which are separable into seven categories; it was scored by assigning numerical values to the appropriate answers: 1 - not at all, 2 - same as usual, 3 - more than usual, and 4 - much more than usual. The HOS is composed of 32 questions concerned with the presence (or absence) of psychiatric signs and symptoms. It is scored similarly to the GHQ, i.e., numerical value assigned to an appropriate answer (1-never, 2-sometimes, or 3-often); possible scores range from 32-96. With both the GHQ and HOS, a direct relationship exists between the degree of symptomatology and the

TABLE 5. General Health Questionnaire (GHQ) and Health Opinion Survey (HOS) Scores

| FDC TEAM | TEST | CONDITION | FDC | COM | RTO | VCO | HCO | $\bar{X} \pm$ S.D. [a] |
|---|---|---|---|---|---|---|---|---|
| 1 | GHQ | Pre[b] | 27 | 59 | 31 | 79 | 46 | $48.4 \pm 21.3$ |
| | | Post[c] | 39 | 32 | 23 | 25 | 38 | $31.4 \pm 7.3$ |
| | HOS | Pre | 44 | 38 | 44 | 43 | 42 | $42.2 \pm 2.5$[d] |
| | | Post | 43 | 37 | 41 | 39 | 37 | $39.4 \pm 2.6$ |
| 2 | GHQ | Pre | 53 | 23 | 33 | 30 | 49 | $37.6 \pm 12.8$ |
| | | Post | 46 | 31 | 58 | 55 | 30 | $44.0 \pm 13.1$ |
| | HOS | Pre | 35 | 43 | 33 | 42 | 38 | $38.2 \pm 6.5$ |
| | | Post | 33 | 44 | 32 | 46 | 35 | $38.0 \pm 6.5$ |
| 3 | GHQ | Pre | 24 | 58 | 39 | 48 | 31 | $40.0 \pm 13.5$ |
| | | Post | 26 | 59 | 33 | 43 | 22 | $36.6 \pm 14.8$ |
| | HOS | Pre | 32 | 41 | 46 | 55 | 39 | $42.6 \pm 8.6$ |
| | | Post | 32 | 47 | 45 | 53 | 34 | $44.2 \pm 7.6$ |
| 4 | GHQ | Pre | 69 | 44 | 110 | 22 | 57 | $60.0 \pm 32.7$ |
| | | Post | 55 | 34 | 40 | 19 | 72 | $44.0 \pm 20.3$ |
| | HOS | Pre | 36 | 42 | 60 | 40 | 65 | $48.6 \pm 13.0$ |
| | | Post | 39 | 45 | 57 | 33 | 70 | $48.8 \pm 14.8$ |

a. Mean $\pm$ Standard Deviation
b. 36 hr before sustained operations
c. 36 hr after sustained operations
d. $P = < .05$

score. Differences between the GHQ and HOS are attributable to the former focusing upon recent changes and the latter upon long-standing symptoms.

Results obtained from the four FDC teams are shown in Table 5. A decrease occurred in mean GHQ scores in Teams 1, 3 and 4 but not in Team 2. Some individuals, however, did not follow the general pattern, e.g., the FDO in Team 1, and HCO in Team 4. Mean HOS scores for the four teams were virtually unchanged with the exception of Team 1 which had a significant decrease in scores. Individual responses showed no consistent patterns in HOS scores. In addition, the changes in symptom categories of the GHQ that occurred pre- and post-testing were examined. Results are shown in Table 6. The data indicate that Team 2's self-rated increase in symptoms was related to general health (feeling ill or rundown, etc.), feelings of fatigue and sleep disturbance, deterioration of personal habits and feelings of inadequacy and increased tension and temper. This contrasted with stability and/or improvement in symptomatology manifested by the other three teams. The finding suggested that Team 2 had not achieved an especially successful adaptation to the stresses of the simulation.

TABLE 6. Changes in General Health Questionnaire Scores by Symptom Category

| | TEAM | | | |
|---|---|---|---|---|
| CATEGORY | 1 | 2 | 3 | 4 |
| A. General Health | -6[a] | +11[a] | +3 | -1 |
| B. Cardiovascular | +1 | +1 | 0 | 0 |
| C. Sleep and Wakefulness | +4 | +12 | -2 | -2 |
| D. Personal Behavior | -4 | +4 | -5 | -6 |
| E. Relations with Other | -2 | -2 | 0 | -5 |
| F. Inadequacy, Tension | -11 | +9 | -3 | -9 |
| G. Guilt and Depression | -6 | 0 | 0 | -7 |
| TOTAL | -24 | +33 | -7 | -30 |

a. - = decrease in symptoms from pre- to post- test

b. + - increase in symptoms from pre- to post- test

Because control mechanism of the parameters evaluated are complex and interactive, it is difficult to draw finite conclusions, but general observations appear warranted: 1) the termination of Team 1 after 48-hr continuous operations does not signify the upper limit of FDC team capability. Team 4 did appear close to functional ineffectiveness when they terminated at 45 hr; although the team's motivation was excellent, the relative inexperience of the enlisted personnel placed continual demands on the FDO and COM. All four teams maintained overall acceptable fire direction performance for 38-hr under the environmental conditions and workload utilized in this study; Teams 2 and 3 repeated this after 34-hr rest (the latter with only four members), indicating substantial reserve capacity. 2) General observations of team output measures confirmed predictions from artillery field experience and scientific reports (15): a) accuracy for primary tasks was generally maintained by all teams with some variability in speed of computation and transmission; b) accuracy and latency for secondary tasks (preplanning) showed variable deterioration even on designated priority targets. This trend progressed in Teams 1 and 4 prior to their voluntary termination, with decrements greatest in the team with the least experience; 3) a 34-hr rest between two 38-hr periods of sustained operation may not be sufficient in all cases to maintain baseline physical work capacity. Inadequate recovery was reflected in decreased 17-OHCS excretion, and increased oxygen uptake and heart rate during submaximal work in some subjects; other factors besides sleep deprivation and sustained arousal, e.g., hypohydration and/or decreased caloric intake may have been involved.

Analyses of performance, urine biochemistries, mood/symptom questionnaires, team social processes, physiological measures, cerebral dominance testing and sleep EEG are continuing collaboratively with WRAIR and NHRC, and are expected to assist in defining this data further.

**Presentations:**

None.

**Publications:**

None.

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Animal Care and Animal Modeling

Investigator: Danney L. Wolfe, CPT, VC

Background:

Over the last six years, the position of Chief, Animal Care Unit has grown to include several responsibilities. These include:

1) surgical development of new and unique animal models to support the research mission of the US Army Research Institute of Environmental Medicine, (USARIEM),

2) performance of aseptic surgical procedures to produce statistically significant numbers of healthy animal models,

3) administrative management of the Animal Care Facility Physical Plant in accordance with (AAALAC) standards American Association for Accreditation of Laboratory Animal Care, and

4) maintenance of the health of the laboratory animal population through the establishment of sound conditioning and preventative medicine programs in accordance with AAALAC standards.

Progress:

Two new animal models were developed in support of the research mission at USARIEM. The first, an unsedated instrumented running mongrel dog model, was prepared in support of the protocol entitled "Pulmonary Gas Exchange During Exercise at Sea Level and Altitude." Each animal utilized in this study was surgically prepared with a permanent tracheostomy, a carotid loop, and a chronically placed Swan-Ganz flow directed catheter. A specially designed stainless steel (impervious to expired inert gases) endotracheal tube with inflatable cuff was inserted through the permanent tracheostomy for the collection of expired gases. The carotid loop was used to obtain arterial blood pressure, arterial blood samples, and heart rate. The chronically placed Swan-Ganz flow directed catheter

Protocols supported by above surgical procedures:

a. WU 024, see page 31
b. WU 022, see page 19
c. WU 001, see page 77
d. WU 042, see page 173

To maintain and guarantee health of the laboratory animals, we have conducted a sound preventative medicine and conditioning program for each of the species. Primates were examined, dewormed, and T. B. tested every six (6) months. Canines were examined, tattoed, and dewormed upon arrival, a routine blood workup (CBC, heartworm check, and "Chem-16" blood chemistry profile) was then performed on each animal. Rats were routinely histologically screened upon arrival for the presence of pneumonitis, they were also screened for pinworms. Goats were examined, deloused, dewormed, and treated for conjunctivitis and placed on prophylactic antibiotics and a sound diet, a routine blood workup (CBC, "Chem-16" blood chemistry profile) was then performed on each animal.

Progress in the administrative management of the animal colony physical plant was marked by re-establishment of full AAALAC Accreditation of the Laboratory Animal Care Facility for the next three years. While the council on accreditation found no problems serious enough to jeopardize accreditation of the facility, it did note some areas in need of improvements. To improve these areas we have: 1) separated the animal technicians lounge from the necropsy area by completely enclosing the necropsy area with floor to ceiling walls, 2) replaced the arrangement of small unhygienic wooden stalls in the goat rooms with new stainless steel "Bob Long Kennel Systems", 3) patched and resurfaced the epoxy floor of the roof housing facility and repaired roof drain, and 4) ordered a new pass-through rack washer and small cage and bottle washer to replace our present deteriorating equipment.

__Presentations:__

1. Presented a seminar at USARIEM entitled, "A running dog model to study pulmonary gas exchange during exericse at sea level and altitude."

2. Presented a seminar entitled, "Goat animal models in support of altitude research at USARIEM." This seminar was given to members of Sigma X-I at their annual meeting." This presentation was awarded the "Sigma XI/RESA Research Achievement Award for Life Sciences.

Publications:

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4. Fencl, V., R. A. Gabel and D. L. Wolfe. Cerebral fluids in prolonged respiratory acid-base imbalance. (In press).

APPENDIX A

INDEX - WORK UNIT STUDIES

Page

APPENDIX B

PUBLICATIONS*

Alpert, J. S., G. A. Beller, S. R. Giamber, and S. B. Saltz. Effects of hypoxia on the hemodynamic actions of prostaglandin $E_1$. Prostaglandins 11:783-797, 1976.

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Banderet, L. E. A squirrel monkey behavioral model for human acute mountain sickness. In: Advances in Medical Primatology. Plenum Press, 1977 (Abstract).

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*In press not included

Bynum, G., K. B. Pandolf, R. F. Goldman, and J. Bull. Human hyperthermia induction: comparison of circulating water suit with other methods. Fed. Proc. 36:512, 1977 (Abstract).

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Hubbard, R. W., R. E. L. Criss, L. E. Elliott, and I. V. Sills. Use of serum enzymes to differentiate in the rat between heat and/or work induced disorders. The Physiologist 20:45, 1977 (Abstract).

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Kowal, D. M. Physical fitness: how to get in shape and stay that way. Soldiers 32:3-8, 1977.

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Sylvester, J. T., and C. McGowan (Spon: M. Landowne). Effect of cytochrome $P_{450}$ inhibitors on the pulmonary vascular response to hypoxia. Fed. Proc. 36:535, 1977 (Abstract).

Szurek, J. L. Design of a real-time peak/valley picking algorithm. Proc. San Diego Biomed. Symp. 15:75-78, 1976.

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Winsmann, F. R., and R. F. Goldman. Methods for evaluation of load carriage systems. Percept. Mot. Skills 43:1211-1218, 1976.

APPENDIX C

## PRESENTATIONS

At Scientific Meetings

Bock, F. M. Calculator-based approach to on-line measurement of oxygen consumption. USAMRDC Information Sciences Symposium, Ft. Sam Houston, TX, 10-14 January 1977.

Breckenridge, J. R., and T. Endrusick. Comparison of thermal properties of NATO materials. CCEW Panel, NATO, Brussels, Belgium, 6-10 June 1977.

Breckenridge, J. R., and R. F. Goldman. Evaluation of thermal insulation benefits from reflective layers in fabric systems. CCEW Panel, NATO, Brussels, Belgium, 6-10 June 1977.

Breckenridge, J. R., O. F. Compagnone, and R. F. Goldman. Characterization of protective insulation of sleeping systems. CCEW Panel, NATO, Brussels, Belgium, 6-10 June 1977.

Burse, R. L., R. F. Goldman, E. Danforth, E. S. Horton, E. A. H. Sims. Effect of excess carbohydrate (CHO) and fat intake on resting metabolism. Federation of American Societies for Experimental Biology, Chicago, IL, April 1977.

Bynum, G., K. B. Pandolf, R. F. Goldman, and J. Bull. Human hyperthermia induction: comparison of circulating water suit with other methods. Federation of American Societies for Experimental Biology. Chicago, IL, April 1977.

Cruz, J. C., J. T. Maher, A. Cymerman, D. L. Wolfe, and E. E. Beekman. Respiratory response to $CO_2$ in goats with chronic metabolic alkalosis at high altitude. XXVII International Congress of Physiological Sciences, Paris, France, 18-23 July 1977.

Cruz, J. C., A. Cymerman, J. T. Maher, and D. L. Wolfe. Role of bicarbonate on alveolar ventilation of the goat during altitude exposure. 20th Annual Lung Conference, Aspen, CO, 8-11 June 1977.

Cymerman, A., J. T. Maher, J. C. Denniston, J. T. Sylvester, J. J. Jaeger, and J. J. Berberich. Effect of 3 days of outdoor physical activity at high altitude on thoracic impedance and alveolar-arterial oxygen gradients. Federation of American Societies for Experimental Biology, Chicago, IL, April 1977.

Evans, W. O. The measurement of pain. Seminar on Selected Topics on Rehabilitation, Boston University, Boston, MA. 19 October 1976.

Francesconi, R. P., J. T. Maher, G. D. Bynum, and J. W. Mason. Recurrent heat exposure: effects on enzyme and potassium efflux in resting and exercising men. Federation of American Societies for Experimental Biology, Chicago, IL, April 1977.

Goldman, R. F. A "balance point" approach to temperature regulation. Federation of American Societies for Experimental Biology, Chicago, IL, April 1977.

Goldman, R. F. Heat stress and adaptation in industrial settings. Joint Meeting: Institute of Industrial Engineers, Rochester, NY, 30-31 March 1977.

Goldman, R. F. Muscular exercise in a thermoneutral environment. Round Table: XXVII Congres International des sciences Physiologiques, Paris, France, 17-23 July 1977.

Goldman, R. F. Using clothing parameters in the practical assessment of comfort. Proc. ASHRAE Symposium on Personal Cooling Fabrics and Heat Stress, Dallas, TX, 1-6 February 1976.

Goldman, R. F. Prediction of human heat tolerance. International Symposium on "Environmental Stress: Individual Adaptations," University of California, Santa Barbara, CA, 31 August-3 September 1977.

Goldman, R. F. Obesity in physical fitness. Combined Joint Medical Research Conference and Training and Personnel Technology Conference; Armed Forces Radiobiology Research Institute, Bethesda, MD, 23-24 May 1977.

Goldman, R. F. Assessment of the thermal environment. Tropical Medicine Course, Walter Reed Army Institute of Research, Washington, DC, 24 August 1977.

Goldman, R. F. Possible fate of ingested calories. Workshop on Adaptive Thermogenesis. Lausanne, Switzerland, 11-12 March 1977.

Goldman, R. F. Clothing and equipment for extreme environments. Mountain Medicine Symposium, Seattle, WA, 8-13 October 1976.

Goldman, R. F. Standards: weighing the problems solved against the problems raised. The Alliance for Electronics in Medicine and Biology, Boston, MA, 10 November 1976.

Goldman, R. F. Human heat transfer. Tutorial: for the Alliance for Electronics in Medicine and Biology (Conference), Boston, MA, November 1976.

Goldman, R. F. Current concepts of the physiological basis for comfort. Symposium on Comfort at the National Bureau of Standards, Gaithersburg, MD, 11 February 1977.

Haisman, M. F., and R. F. Goldman. Intensity of repeated exercise and the cardiorespiratory training response. XXVII Congres International des Sciences Physiologiques, Paris, France, 17-23 July 1977.

Horstman, D. H. Exercise performance at 5°C. American College of Sports Medicine, Chicago, IL, May 1977.

Jackson, R. E. Ventilatory acclimatization to altitude and altitude complications of medical problems. Second Annual High Altitude Medical Symposium, Frisco, CO, 3 October 1976.

Jaeger, J. J., J. T. Maher, J. C. Denniston, J. T. Sylvester, A. Cymerman, and J. J. Berberich. Changes in closing capacity and lung volumes during 3 days of physical activity at high altitude. Federation of American Societies for Experimental Biology, Chicago, IL, April 1977.

Kowal, D. M. The role of the Psychologist in physical fitness research. Current Trends AMEDD Behavioral Science Course, WRAIR, Washington, DC, 6-10 June 1977.

Kowal, D. M. Psychological aspects of exercise physiology currently under investigation. 1977 APA Convention - Symposium entitled "Contributions of Psychologists to Environmental Medical Research in US Army," San Francisco, CA, 26-30 August 1977.

Kowal, D. M., J. A. Vogel, and J. Peterson. Comparison of strength and endurance training on aerobic power in young women. *24th Annual Meeting* of American College of Sports Medicine, Chicago, IL, 25-28 May 1977.

Maher, J. T., J. C. Denniston, D. L. Wolfe, and A. Cymerman. Mechanism of the attenuated cardiac responsiveness to β-adrenergic stimulation in chronic hypoxia. XXVII International Congress of Physiological Sciences, Paris, France, 18-23 July 1977.

McCarroll, J. E. Participant observation of stress of cold weather military training and its effect on group and individual performance. 1977 APA Convention entitled "Contributions of Psychologists to Environmental Medical Research in US Army", San Francisco, CA, 26-30 August 1977.

Pandolf, K. B. The influence of local and central factors in dominating rated perceived exertion during physical work. Symposium entitled "Perceived Exertion: A Quest for Psychophysiological Mechanisms" at the 1977 American Alliance for Health, Physical Education & Recreation National Convention, Seattle, WA, 25-29 March 1977.

Pandolf, K. B. The influence of hot environments on human performance of muscular exercise. XXVII Congres International des Sciences Physiologiques, Paris, France, 18-23 July 1977.

Pandolf, K. B., and R. F. Goldman. The convergence of skin and rectal temperatures as a criterion for heat tolerance. Lille Satellite Symposium on Temperature Regulation, Lille, France, 10-13 July 1977.

Pandolf, K. B., R. L. Burse, B. Givoni, R. G. Soule, and R. F. Goldman. Predicting rectal temperature and heart rate responses to dehydration while working in the heat. International Congress of Physiological Sciences, Paris, France, 18-23 July 1977.

Pandolf, K. B., R. L. Burse, B. Givoni, R. G. Soule, and R. F. Goldman. Effects of dehydration on predicted rectal temperature and heart rate during work in the heat. 24th Annual American College of Sports Medicine Meeting, Chicago, IL, 25-28 May 1977.

Pandolf, K. B. Perceived exertion during physical work. Noll Laboratory for Human Performance Research, the Pennsylvania State University, University Park, PA, 2 November 1976.

Pandolf, K. B. Heat stress and physical performance. Human Energy Research Laboratory, University of Pittsburgh, PA, 4 November 1976.

Pandolf, K. B. Interaction of fitness with heat tolerance. Tropical Medicine Course, Walter Reed Army Institute of Research, Washington, DC, 24 August 1977.

Ramos, M. U., and J. J. Knapik. Rate of isometric peak torque development in the intact human: preliminary report. American Congress of Rehabilitation Medicine and American Academy of Physical Medicine & Rehabilitation Annual Meetings, San Diego, CA, 7-12 November 1976.

Ramos, M. U. Comparison of isotonic, isometric and isokinetic strength trainings programs under standardized, controlled experimental conditions. American Congress of Rehabilitation Medicine and American Academy of Physical Medicine & Rehabilitation Annual Meetings, San Diego, CA, 7-12 November 1976.

Ramos, M. U. Establishment of a muscle strength laboratory. Tufts NE Medical Center (Seminar to Medical Staff), Boston, MA, 22 October 1976.

Ramos, M. U. Development of the muscle strength laboratory at the US Army Research Institute of Environmental Medicine. American Congress of Rehabilitation Medicine and American Academy of Physical Medicine & Rehabilitation Annual Meetings, San Diego, CA, 7-12 November 1976.

Sampson, J. B. Psychological factors of cold adaptation and a technique of intervention for cold hypersensitivity. 1977 APA Convention - Symposium entitled "Contributions of Psychologists to Environmental Medical Research in US Army," San Francisco, CA, 26-30 August 1977.

Sampson, J. B. Anxiety and the temperature response of the hand to cold. 16th Annual Convention of Society for Psychophysiological Research, San Diego, CA, 20-23 October 1976.

Strauss, R. H., J. Jaeger, R. H. Ingram, Jr., and E. R. McFadden, Jr. Effects of cold air on the bronchoconstrictor response to exercise in asthma. American Federation for Clinical Research, Washington, DC, 30 April-1 May 1977.

Sylvester, J. T., and C. McGowan (Spon: M. Landowne). Effect of cytochrome $P_{450}$ inhibitors on the pulmonary vascular response to hypoxia. Federation of American Societies for Experimental Biology, Chicago, IL, April 1977.

Vogel, J. A. Aerobic fitness and muscle strength of women entering the US Army. Symposium on Women at West Point, American Alliance for Health, Physical Education & Recreation, Seattle, WA, March 1977.

Vogel, J. A. Aerobic fitness in young people. New England College Health Association Meeting, Wellesley College, MA, 6 November 1976.

Vogel, J. A., M. U. Ramos, and J. F. Patton. Comparisons of aerobic power and muscle strength between men and women entering the US Army. 24th Annual Meeting of American College of Sports Medicine, Chicago, IL, May 1977.

Other Presentations

Banderet, L. E., J. W. Stokes, P. W. Phair and D. M. McKenzie. Psychological determinants of work performance, and effects of sleep loss and rapid translocation. US Army Research Institute of Environmental Medicine Course, Natick, MA, 17 May 1977.

Burse, R. L. Environmental research to extend the soldier's performance capabilities. 1037th USA Reserve School, Boston Army Base, MA, 17 March 1977.

Goldman, R. F. Industrial work in a cold environment, its assessment and limitations. University of Buffalo, Buffalo, NY, 30-31 March 1977.

Goldman, R. F. Physiological problems of operating in a toxic environment. DoD Research & Engineering Topical Review of Chemical Warfare Personal Protective Equipment Programs, Natick, MA, 19-20 May 1977.

Hamlet, M. P. Operational problems in Alaska/summary of after-action reports. 1st Battalion (ABN) 504th Infantry, Ft. Bragg, NC, 3-6 November 1976.

Jaeger, J. J. Short summary of data collected from summer study at Pikes Peak facility in 1976. Presented before a group of Scientists at the General Motor's Research Center, Warren, MI, 21 February 1977.

Pandolf, K. B. Importance of physical fitness in heat acclimatization. The Noll Laboratory at the Pennsylvania State University, University Park, PA, 2 November 1976.

Stokes, J. W. Effects of sustained operations and sleep loss. Course on special operations, P.O.C.: LTC Harry J. Bacas, Dept. of Tactics, C&GS, Ft. Leavenworth, KS, 21 January 1977.

Sylvester, J. T. Effects of inhibitors of cytochrome $P_{450}$ on the pulmonary vascular response to hypoxia. University of Miami School of Medicine, Miami, FL, 19-21 September 1976; Johns Hopkins School of Medicine, Baltimore, MD, 29 September to 1 October 1976; University of California, Harbor Hospital (UCLA), Los Angeles, CA, and SF General Hospital, San Francisco, CA, 5-8 October 1976.

## APPENDIX D

## CONSULTATIONS

| Date | Requesting Individual/Agency | Subject |
|---|---|---|
| 5 Oct 76 | LTC George Stebbing<br>Hqtrs DARCOM<br>DRC-SG<br>Alexandria, VA 22333 | Safe time for wear of the M3 suit |
| 19 Oct 76 | COL William A. Akers<br>Letterman Army Institute of Research<br>Presidio<br>San Francisco, CA 94129 | Paddy foot problem |
| 26 Oct 76 | Warren Bowman, M.D.<br>Billings Clinic<br>Box 2555<br>Billings, Montana 59103 | Blood clotting mechanisms at high terrestrial elevations |
| 27 Oct 76 | Mr. Norman Dvoskin<br>Grumman Aerospace<br>Beth Page, NY 11714 | Moisture pickup of advanced composite materials for aircraft |
| 2 Nov 76 | Alan Ewert<br>Fairchild Air Force Base<br>Washington 99011 | Survival science and energy cost of various tasks |
| 4 Nov 76 | Captain Douglas Hoon<br>Cold Regions Test Center<br>ATTN: STECR-TD<br>APO Seattle 98733 | Field evaluation at Ft. Greeley on the new black foam boot |
| 15 Nov 76 | Mr. J. H. Nix<br>FAA/CAMI-AA143<br>Oklahoma City, OK 73125 | Survival courses for FAA pilots |
| 19 Nov 76 | Dr. Arnold W. Thornton<br>Cardiac Pacemakers, Inc.<br>St. Paul, MN 55112 | Heart rate and its responses to exercise and heat |
| 23 Nov 76 | US Army Institute of Dental Research<br>ATTN: Thomas F. Payne, MAJ<br>Walter Reed Army Medical Center<br>Washington, DC 20102 | Solar radiation and protecting the skin from sunburn |

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| 24 Nov 76 | Mr. William N.McKinnery, Jr.<br>National Institute for Occupational Safety and Health<br>Robert A. Taft Laboratories<br>Cincinnati, OH 45226 | Heat stress computer program |
| 2 Oct 76 | 2nd Annual High Altitude Medical Symposium<br>Frisco, CO | Medical problems in altitude |
| Dec 76 | National Guard Unit<br>Oregon | Projected training for Camp Roberts, CA, in July 1977 |
| 1 Dec 76,<br>22 Feb 77 | USAIS<br>Ft. Benning, GA | Review of baseline fitness field test program |
| 3 Dec 76 | US Army Tank Automotive R&D Command<br>ATTN: DRXHE-TA/CPT Sheetz<br>Warren, MI 08090 | Tolerance and discomfort of troops in cold armored fighting vehicles (AFV) |
| 6 Dec 76 | Public Affairs Office<br>Fort Devens, MA | Movie - "Cold Weather Injury Prevention" |
| 8 Dec 76 | Larry Nicodemus<br>National Climatic Center<br>Asheville, NC | Cold and performance |
| 22 Dec 76 | MAJ Michael Sisk, MC<br>Chief, Health & Environmental Medicine<br>Fort Carson, CO | Cold weather briefing to 700 medical and paramedical personnel at Fort Carson on 3 Jan 77 |
| 28 Dec 76 | 10th Special Forces<br>Gorham, NH | Military cold weather training |
| 30 Dec 76 | Mr. James Cambridge<br>Principal L'Anse Creuse Public Schools<br>Emma V. Lobbestael Elementary School<br>Mount Clemens, MI 48043 | Windchill and safety for recess of elementary grade school children |
| Jan 77 | HQDA(DASG-HCO-O/Ms. L. Nearing) | Allowances for Blanket, Bed, Wool, OG (LIN B72225) and Liner Wet Weather Poncho (LIN L70789) |
| 4 Jan 77 | USAMRDC | Evaluation of application for support of research |

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| 5 Jan 77 | LTC Harry J. Bacas<br>Dept of Tactics<br>Command General Staff<br>Ft. Leavenworth, KA | 3-hr teaching block on (1) medical aspects of cold weather operations; (2) operational problems in cold environments; (3) medical and operational problems of mountainous operations; (4) recent clothing and equipment development |
| 7 Jan 77 | 47th Infantry Division<br>Camp Ripley, MN | Cold weather winter warfare training exercise |
| 7 Jan 77 | Mr. Robert Walker<br>Walterville Ski Touring<br>Walterville, NH 03233 | Cold injuries especially recent advances in treatment and management of cold injuries |
| 7,11 Jan 77<br>23 Feb 77<br>7 Mar 77<br>15 Aug 77 | DA-DCSPER<br>Pentagon<br>WASH, DC | Utilization of women in the Army and physical fitness requirements |
| 28 Jan 77 | USAMRDC | Evaluation of application for support of research |
| Feb 77 | Duluth Herald News<br>Duluth, MN | Psychological effects of prolonged cold |
| 1 Feb 77 | Mr. Herbert Sperry<br>ACTION<br>PO Courthouse<br>Boston, MA 02109 | Thermal comfort for the elderly |
| 1 Feb 77 | Captain Chandler<br>USAF Hospital<br>SGPM<br>Little Rock AFB<br>Jacksonville, AR 72076 | Safety for flight line work |
| 1 Feb 77 | Charles Fafard<br>DILMR<br>Madison, WI 53707 | Absolute minimum temperatures for work sites |
| 1 Feb 77 | Mr. L. O. Walker<br>Bell & Howell Company<br>Chicago, IL 60645 | Safe exposure of workers to -80°F during conduct of end item tests for the Army |
| 11 Feb 77 | Ms Mia Mora<br>Stanford Research Institute<br>333 Ravenwood Ave.<br>Menlo Park, CA 94025 | Request for information on hypothermia |

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| 14 Feb 77 | LTC Victor Furtado<br>USAF Sch Aerospace Medicine<br>San Antonio, TX | Response of students to classroom temperatures of 65°F |
| 14 Feb 77 | Dr. Richard A. Maganck<br>Oregon State University<br>Department of Resource Recreation Management<br>Corvallis, OR 98331 | Thermavision slides - effect of constriction from clothing or boots - frostbite damage |
| 15 Feb 77 | MEDDAC<br>Ft. Riley, KS | Physical fitness program for women |
| 15 Feb 77 | CPT Mike Kastello<br>Aerobiology Div<br>USAMRIID<br>Frederick, MD | The hemodynamics and physiology of fluid exchange in pulmonary lavage |
| 16 Feb 77 | Dr. Joseph Kohler<br>Chemical Engineering Dept<br>Worcester Polytechnic Institute<br>Worcester, MA 01609 | Windchill and cold injury |
| 17 Feb 77 | LTC Paul Hildebrandt<br>Director, Pathology Div<br>WRAIR | Can the effects of noise or associated shock wave of large artillery piece cause pulmonary damage? |
| 23 Feb 77 | Dr. Konzen<br>Texas A&M University | Cold stress - hand dexterity and productivity |
| Mar 77 | MEDDAC<br>Fort Knox, KY | Foot problems in basic trainees |
| 4 Mar 77 | Mr. Dan Macy<br>Texaco Inc.<br>New Orleans, LA | Risk of radiant heat; burning off the exhaust gas from north sea oil wells |
| 9 Mar 77 | Mr. J. Corlack<br>Chief, US Army Eng. Lab Det.<br>Picatinny Arsenal<br>Dover, NJ | Maximum missile loads that can be carried by the soldier |
| 10 Mar77 | USAMRDC | Evaluation of application for support of research |
| 14 Mar 77 | Mr. Michael Coveyou<br>Research and Budget Office<br>City of Des Moines<br>Des Moines, IA 50307 | Kevlar armor |

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| 16 Mar 77 | Gregory W. Lewis, Ph.D.<br>US Navy Personnel R&D Ctr.<br>San Diego, CA and<br>LTC Robert J. Biersner<br>Scientific Director<br>Naval Sub. Med. Res. Lab.<br>Groton, CT | Assessment of performance of real teams in sustained operations |
| 25 Mar 77 | Franklin Institute<br>Philadelphia, PA | Cold standards |
| 28 Mar 77 | Mr. Richard Thibeault<br>Science Department<br>Lexington High School<br>Lexington, MA 02173 | Computer prediction of heat production and environmental responses |
| 7 Apr 77 | Division Surgeon<br>4th Infantry Division<br>ATTN: CPT Kurano<br>Fort Carson, CO 80913 | Mineral supplementation and acute mountain sickness symptoms |
| 7 Apr 77 | Mr. John Chan &<br>Mr. Peter Sullivan<br>Fiber Physics Department<br>Celanese Research Company<br>New Jersey | Theory and construction details of the "sweating" guard ring flat plate |
| 15 Apr 77 | Dr. J. Walter Giffee,<br>Roland A. Segars,<br>and Nancy Cobean,<br>Food Sciences Laboratory, &<br>Donald F. Kass, MISO<br>US Army Natick R&D Command<br>Natick, MA 01760 | Cost analysis and impact of centralized vs de-centralized minicomputer data acquisition |
| 15 Apr 77 | Fort Rucker, AL | Influence of cold on aeromedical operations |
| 21-22 Apr 77 | USAMBERDL, MD | Cold injury rapid warming device |
| 28 Apr 77 | COL Joseph R. Zbylski, MC<br>Department of Surgery<br>Fitzsimons Army Medical Center<br>Denver, CO 80240 | Hypoxia-induced medical problems |
| May 77 | 4th Infantry Div., and<br>Medical Personnel at<br>Ft. Carson, CO | Medical problems associated with operations in hot environments |

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| 2 May 77 | CPT Navin, CPT C. Riemer, and SSG E. Lopes<br>1-211st FA Bn<br>24th Inf. Div.<br>New Bedford & Fall River, MA | Training of FDC teams for sustained operations |
| 4 May 77 | Larry W. Price, Ph.D.<br>Department of Geography<br>Portland State University<br>P.O. Box 751<br>Portland, Oregon 97207 | Operation of motorized equipment at high altitudes |
| 6 May 77 | Ted Putnam<br>United States Dept. of Agriculture<br>Forest Service<br>Fort Missoula<br>Missoula, MI 59801 | Heat stress while wearing protective clothing in hot environments |
| 10 May 77 | Office of The Surgeon General | Evaluation of research proposal |
| 11 May 77 | Hqtrs USA Logistics Center<br>Concepts & Doctrine Directorate<br>LTC Delma George<br>Fort Lee, VA 23801 | Recommended design standards for lifting in the Military (MIL-STD-1472B); frequency and weight acceptable to male and female industrial workers |
| 13 May 77 | Division Surgeon's Office<br>7th Infantry Division and Fort Ord<br>AZFW-PA-DS/LT Hodges<br>Fort Ord, CA 93941 | Operations in a toxic environment |
| 13 May 77 | Army Human Engineering Lab.<br>Aberdeen Proving Grounds<br>Aberdeen, MD | Measurement of physical fitness for entry into Army |
| 17 May 77 | Army Research Institute<br>Alexandria, VA | Physical fitness requirements |
| 24 May 77 | Mr. Wm Donnally<br>ARRADCOM<br>Dover NJ | Physiological measurements |
| 1 Jun 77 | Ms. Jackie Goldenberg<br>Medical Editor<br>Woman's Day Magazine<br>1515 Broadway<br>New York, NY 10036 | General information on cold, and effects of foods, alcohol, smoking and humidity in the cold |

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| 6 Jun 77 | John G. Muller<br>Federal Energy Administration<br>Washington, DC 20461 | Summer comfort and energy conservation |
| 6 Jun 77 | Mr. Perry Kressh<br>Occupational Environmentalist<br>Los Angeles County Department of Personnel<br>Los Angeles, CA 90012 | LA county problem with employees working in a cold room at +35 or a freezer at -10$^{o}$F |
| 6 Jun 77 | US Coast Guard Headquarters<br>ATTN: LT W.W. Reid<br>G-PCSP/61<br>Washington, DC 10590 | Exposure/immersion suits |
| 7 Jun77 | Joe Neidhardt, P.E.<br>Wander Incorporated<br>1018 Proprietors Road<br>Worthington, OH 43085 | Loss of productivity for construction workers in cold weather |
| 7 Jun 77 | Dr. Ron Williams<br>Assistant Chief, Pediatric Service<br>Fitzsimmons Army Medical Center<br>Denver, CO | Review of protocol and information on altitude research |
| 17 Jun 77 | Kirby Hanson, Ph.D.<br>National Oceanic & Atmospheric Administration<br>RF 329<br>Boulder, CO 80302 | Cardiac problems at high elevations |
| 20 Jun 77 | Mr. Arthur Woodward<br>US Army Human Engineering Laboratory<br>Aberdeen Proving Ground<br>Aberdeen, MD | Human factors data on women performing military tasks |
| 20 Jun 77 | Mr. Snowden<br>Stop & Shop<br>Boston, MA | Effect of temperature and humidity on warehouse workers |
| 22-24 Jun 77 | USAMRDC | Site visit in connection with University of Wisconsin contract |

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| 24 Jun 77 | Director<br>TARADCOM Detachment<br>USA Human Engineering Lab<br>ATTN: DRXHE-TA/James A. Erickson<br>Warren, MI 48090 | Maximum comfort temperatures for military personnel dressed in arctic clothing |
| 29 Jun 77 | LTC Barrett<br>US Army Public Affairs<br>New York, NY 10022 | Films: laboratory studies on heat rash - chemical protective clothing - cold and high terrestrial elevation |
| 8-22 Jul 77 | Twenty-nine Palms, CA | Observers in Brave Shield XVI, and assessed Army, Marine, and Air Force preparations and implementation of current medical doctrine for hot weather operations; also determined the extent of incurred heat injuries |
| 13 Jul 77 | Workmanship Unit, USAIS<br>Ft. Benning, GA | Fitness and energy expenditure |
| 14 Jul 77 | Bruce Commons, USAHEL<br>Aberdeen Proving Grounds, MD | Equilibration of skin temperatures with the environmental temperatures |
| 18 Jul 77 | Dr. William Mills<br>& the USAMBERDL staff<br>Washington, DC | Cold weather injury rewarming device |
| 19 Jul 77 | MAJ Joseph C. Denniston, VC<br>US Army Aeromedical Research Laboratory<br>Fort Rucker, AL 36362 | Visual performance and perceptual efficiency as related to pilot performance |
| 21 Jul 77 | Philip Eastley<br>P.O. Box One<br>Snowbird<br>Utah 84070 | Hypothermia |
| 26 Jul 77 | Major Samuel Boothby, MSC<br>75 Gray Road<br>Gorham, ME 04039 | Problems of evacuation in the cold |
| 27 Jul 77 | T. H. Nilsson<br>Research Associate<br>Department of Psychology<br>University of Alberta<br>Edmonton, Alberta T6G 2E9<br>Canada | Arctic wind tunnels |

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| 2 Aug 77 | Dr. John Currie<br>Flight Surgeon<br>Salem, OR | Nomex flight uniforms |
| 2 Aug 77 | COL Schlatter<br>Division Surgeon | Jogging and stress and fractures; environmental stress and Cu man analyses |
| 12 Aug 77 | Office of the Division Surgeon<br>7th Infantry Division<br>ATTN: 2LT Kirk Hodges<br>Fort Ord, CA 93941 | Prevention of cold injury |
| 12 Aug 77 | James M. Jay, M.D.<br>1645 Hall Place<br>Indianapolis, IN 46202 | Treatment of high altitude pulmonary edema |
| 16 Aug 77 | LCDR Al Miller<br>Code 142<br>Naval Safety Center<br>NAF<br>Norfolk, VA 23511 | Performance decrement in cold environments |
| 16 Aug 77 | MET and E<br>AHS<br>ATTN: Ms. Wylie<br>P.O. #1, Box 9 | Individuals to be able to counteract the fall in environmental temperatures by increasing clothing and exercise |
| 19 Aug 77 | Directorate of Combat Developments<br>US Army Intelligence Center and School<br>ATTN: ATSI-CD-CS<br>Fort Huachuca, AZ 85613 | Review of Manual FM 30-11/AFM 105-4, Weather Support for Army Tactical Operations ACN: 1000 |
| 22 Aug 77 | Ingvar Holmer (Prof)<br>Nat'l Board of Occupational Safety & Health<br>Dept of Occupational Health<br>Stockholm, Sweden | Problems of heat and cold stress in industry |
| 22 Aug 77 | U.S. News and World Globe Magazine | Nutrition in the cold |
| 2 Sep 77 | Mr. Michael O'Brien<br>Trent University<br>Peterboro, Ontario<br>Canada | Reduction of ambient temperature, comfort ventilation rate, lighting levels and their impact on workers |

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| 6 Sep 77 | Dr. C. Lambertson<br>Institute for Environmental<br>Medicine, Univ of PA Med School<br>Philadelphia, PA | Prediction of work capacities |
| 9 Sep 77 | Mr. Bruce McCommons<br>USA Human Engineering Lab<br>Aberdeen Proving Ground, MD | Conditioning field electronics vans |

## APPENDIX E

BRIEFINGS/LECTURES

Banderet, L. E. "The Field Artillery Fire Direction Center as a Laboratory Model for Studying the Effects of Sustained Operations." Briefing for 1/211 FA Bn, 24th Inf. Div., New Bedford, MA, Jan 77.

Banderet, L. E., and J. W. Stokes. "The Field Artillery Fire Direction Center as a Sustained Operation, Laboratory Simulation." Briefing for Dr. Martin Allnutt of Army Personnel Research Establishment, Farnborough, England, at Natick, MA 2-4 May 77.

Banderet, L. E., and J. W. Stokes. "The Field Artillery Fire Direction Center: A Laboratory Tool for Studying Biomedical Problems of Sustained Operations." Briefings for Division Artillery Cdr, Division Surgeon, and S3 to XVIII Corps Surgeon, Ft. Bragg, NC, 4-5 Oct 76.

Dangerfield, H. G. "Research in Environmental Stress" to Community Health and Environmental Science Course, Academy of Health Sciences, Ft. Sam Houston, TX, 9 Nov 76.

Dangerfield, H. G. Presentation at Annual Meeting of the Society of Medical Consultants to the Armed Forces, Holiday Inn, Bethesda, MD, 21-22 Nov 76.

Dangerfield, H. G. Briefing to Defence and Civil Institute of Environmental Medicine, Downsview, Ontario, Canada, 5 Dec 76.

Dangerfield, H.G. "Research in Environmental Stress" to Community Health and Environmental Science Course, Academy of Health Sciences, Ft. Sam Houston, TX, 11 May 77.

Dangerfield, H. G. "Research in Environmental Stress" to Community Health and Environmental Science Course, Academy of Health Sciences, Ft. Sam Houston, TX, 1 Aug 77.

Dangerfield, H. G. Briefed representatives of OTSG and DCSPER on the AFEES Study; and attended the USAIS Physical Fitness Conference at Ft. Benning, GA, 15-18 Aug 77.

Goldman, R. F. Lecture on "Special Tactical Operations for Maneuver Units," USA Command and General Staff College, 20-21 Jan 77.

Goldman, R. F. Topical Review of Chemical Warfare; Personal Protective Equipment Program- "Physiological Problems of Operating in a Toxic Environment," USANARADCOM, Natick, MA, 19 May 77.

Goldman, R. F., and K. B. Pandolf. Lectures on "Tropical Medicine," WRAIR, Washington, DC, 24 Aug 77.

Hamlet, M. P. Cold weather briefing to 1/504th AB Inf. Battalion; A Battery, 2/321st ABN FA; and 1-17AB Cavalry. To raise level of preparedness for cold weather training. Ft. Bragg, NC, 3-5 Nov 76.

Hamlet, M. P. Participate in Cold Weather Material Requirements Conference; develop understanding within The Surgeon General's Staff of the impact of cold on equipment and subsequent impact on cold weather evacuation. Ft. Leavenworth, KS, 9-12 Nov 76.

Hamlet, M. P. Brief staff physicians on treatment of frostbite and hypothermia, Ft. Devens, MA, 19 Nov 76.

Hamlet, M. P. Brief USMC, 1st Battalion, 25th Marines, 4th Marine Division, FMF, USMCR Training Center in preparing for cold weather training in Alaska (Operation Jack Frost). Westover Air Force Base, Chicopee, MA, 4 Dec 76.

Hamlet, M. P. Brief 402nd Army Security Agency Div. (Special Operations - Airborne) prior to survival training in Maine. Ft. Devens, MA, 7 Dec 76.

Hamlet, M. P. Brief Marine Corps Officers on Cold Weather Operations prior to cold weather training. Camp Lejeune, NC, 10 Dec 76.

Hamlet, M. P. Brief MEDDAC and Command staff, and the troops (4th Div.), prior to cold weather exercises. Ft. Carson, CO, 2-4 Jan 77.

Hamlet, M. P. Brief personnel of Exercise Alpine Warrior and Marine Corps on prevention of cold injuries prior to going to Camp Drum. Camp Lejeune, NC, 5-7 Jan 77.

Hamlet, M. P. Brief military medical personnel on cold injury with special emphasis on trench foot. Ft. Bragg, NC, 1-2 Feb 77.

Hamlet, M. P. Brief Dartmouth Medical School on cold exposure. Hanover, NH, 7 Feb 77.

Hamlet, M. P. Presentations on "Cold Weather Problems," Hampshire College, Amherst, MA, 3 Mar 77.

Hamlet, M. P. Talk on "Hypothermia" to New England College Health Personnel, Dartmouth, MA 30 Apr 77.

Hamlet, M. P. Cold weather talk, Buckingham, Brown and Nichols School, Boston, MA, 18 May 77.

Hamlet, M. P. Annual briefing on cold injury, prevention and management given to Navy physicians, assistants and corpsmen assigned to icebreakers and land duty in Antarctica (Operation Deep Freeze). Oakland, CA, 24-26 Aug 77.

Hamlet, M. P. Briefing to civilian scientist going to Antarctica on prevention and recognition of cold injury. Scotsdale, AZ, 19-21 Sep 77.

Hubbard, R. W. Lecture on "Career Opportunities in Environmental Medicine," Framingham South High School Career Day, Framingham, MA, 9 Mar 77.

Hubbard, R. W. Lecture on "Animals in Science," Explorers Group, USANARADCOM, Natick, MA, 31 Mar 77.

Hubbard, R. W. Lecture on "Heat Illness - A Challenge for Environmental Medicine," Framingham North High School Career Exposition, Framingham, MA, 14 Apr 77.

Hubbard, R. W. Lecture on "Biochemistry," Springfield College, Springfield, MA, 21 Apr 77.

Hubbard, R. W. Lecture on "Prevention, Diagnosis, and Treatment of Heat Illness," Ft. Carson, CO, 5-7 May 77.

Hubbard, R. W. Lecture on "Heat Illness: Prevention, Diagnosis, and Treatment," The WRAIR Course, Washington, DC, 19 May 77.

Hubbard, R. W. Lecture on "The Treatment, Prevention, Etiology, and Diagnosis of Heat Illness," WRAIR, Washington, DC, 24 Aug 77.

Kowal, D. M. Armed Forces Epidemiology Board on "Development of Physical Fitness Entry and MOS Standards," Bethesda, MD, 10 Mar 77.

Patton, J. F. Symposium on the Female Athlete, "Physiological Capabilities of Female Athletes," Children's Hospital, Boston, MA, 16 May 77.

Stokes, J. W. "Medical Problems of Sustained Operations." Briefing for TRADOC Scientific Advisor, Surgeon, and other staff, Ft. Monroe, VA, 21 Mar 77.

Stokes, J. W. "The Field Artillery Fire Direction Center: A Laboratory Tool for Studying Biomedical Problems of Sustained Operations." Briefings for XVIII Corps Surgeon, Ft. Bragg, NC, 22 Mar 77.

Stokes, J. W. "Assessing the effects of Sustained Operations with Laboratory Simulations and Field Tests." Briefing for COL M.D. Thomas, MC (US Army Liaison Officer to Ministry of Defense, London), at Natick, MA, 19 Jul 77.

Vogel, J. A. Army DCSPER Meeting on Physical Requirements for MOS Skills on "Physical Fitness Research Efforts by OTSG and USARIEM," Washington, DC, 11 Feb 77.

Vogel, J. A. Combined Meeting of the Joint Medical Research Conference and the Training and Personnel Technology Conference - "Physical Fitness in the Army," Bethesda, MD, 24 May 77.

Vogel, J. A. Tropical Medicine Course on "Assessment and Current Status of Physical Fitness in the Army," WRAIR, Washington,DC, 24 Sep 77.

APPENDIX F

CONSULTATIONS, BRIEFINGS AND PRESENTATIONS PERFORMED BY USARIEM PERSONNEL FOR INCREASED INFORMATION DISSEMINATION

CONSULTATIONS:

1. Denniston, J. C., MAJ, VC

Organization Visited: US Army Aeromedical Research Laboratory
Fort Rucker, AL

Purpose: Consult on the influence of cold weather on aeromedical operations.

2. Goldman, R. F., Ph.D.

Organization visited: Webb Associates
Yellow Springs, Ohio

Purpose: Consult to review contract work in temperature regulation.

3. Hamlet, M. P., D.V.M.

Organization Visited: Fort Leavenworth, Kansas

Purpose: Participate in Cold Weather Material Requirements Conference.

4. Jackson, R. E., MAJ, MC

Organization Visited: MEDDAC, Fort Knox, Kentucky

Purpose: Consult with MEDDAC on recurrent foot problems in basic trainees.

BRIEFINGS:

1. Goldman, R. F., Ph.D., Hamlet, M.P., D.V.M., Franz, D. R., CPT, VC, Pierce, D. R., SFC

Organization Visited: Fort Bragg, NC

Purpose: Brief medical personnel on cold injuries and cold weather survival.

2. Hubbard, R. W., Ph.D.

Organization Visited: Fort Carson, Colorado

Purpose: To brief personnel on medical problems associated with operations in warm environments.

PRESENTATIONS:

1. Goldman, Ralph F., Ph.D.

   Place: US Army Command and General Staff College
   Fort Leavenworth, Kansas

   Topic: Special Tactical Operations for Maneuver Units

2. Hamlet, Murray P., D.V.M.

   Place: Hampshire College
   Amherst, MA

   Topic: Cold Weather Survival and Cold Injuries

3. Jackson, Ronald E., MAJ, MC

   Place: 2nd Annual High Altitude Medical Symposium
   Frisco, Colorado

   Topic: Medical problems associated with operations at high terrestrial elevations

## APPENDIX G

## SEMINAR PROGRAM

| DATE | LECTURER | SUBJECT |
|---|---|---|
| 12 October 1976 | Regius McFadden, M.D.<br>Associate Professor of Medicine<br>Harvard Medical School<br>Peter Bent Brigham Hospital<br>Boston, Massachusetts | Mechanisms of Exercise Induced Asthma |
| 14 October 1976 | Brian Sharkey, Ph.D.<br>Department of Physical Education<br>University of Montana<br>Missoula, Montana | Fitness and Work Capacity: Applications for the U.S. Department of Agriculture Forest Service |
| 10 November 1976 | L.A. Geddes, Ph.D.<br>Director, Biomedical Engineering Center<br>Purdue University<br>Lafayette, Indiana | Recent Developments in Ventricular Defibrillation |
| 17 November 1976 | Fabian J. Lionetti, Ph.D.<br>Center for Blood Research<br>Boston, Massachusetts | Isolation of Cyropreservation of Human Granulocytes |
| 9 December 1976 | Jerome A. Dempsey, Ph.D.<br>Associate Professor<br>Department of Preventive Medicine<br>University of Wisconsin<br>Madison, Wisconsin | Pulmonary Response to Muscular Work in Hypoxia |
| 26 January 1977 | Stanley N. Gershoff, Ph.D.<br>Associate Professor of Nutrition<br>Department of Nutrition<br>Harvard School of Public Health<br>Boston, Massachusetts | Studies on the Effect of Nutrient Fortification of Rice in Thailand |
| 18 February 1977 | CPT Douglas J. Ramseth, MSC<br>Chief, Clinical Engineering Team<br>US Army Tri-Service Medical Information Systems Agency(TRIMIS-Army)<br>Walter Reed Army Medical Center<br>Washington, DC | Computer-Assisted Practice of Cardiology: The Capoc System |

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| 7 April 1977 | Brian J. Whipp, Ph.D.<br>UCLA Los Angeles<br>Harbor General Hospital<br>Torrance, California | Dynamics of Gas Exchange During Exercise |
| 28 April 1977 | Jacques LeBlanc, Ph.D.<br>Professor, Department of Physiology<br>Laval University<br>Quebec, Canada | Adaptation of Man to Cold |
| 12 May 1977 | Carl V. Gisolfi, Ph.D.<br>Associate Professor<br>Department of Physiology & Biophysics<br>University of Iowa<br>Iowa City, Iowa | Effects of Training on Heat Tolerance |
| 2 June 1977 | L.C. Senay, Jr., Ph.D.<br>Professor of Physiology<br>St. Louis University Medical School<br>St. Louis, Missouri | Effects of Training and Heat Acclimatization on Blood Plasma Contents of Exercising Men |
| 8 June 1977 | Richard Surwit, Ph.D.<br>Massachusetts Mental Health Center<br>Boston, Massachusetts | The Application of Biofeedback in the Treatment of Raynaud Patients |
| 15 June 1977 | Martin T. Orne, M.D., Ph.D.<br>Professor and Head<br>Experimental Psychiatry Unit<br>The Pennsylvania Hospital<br>Philadelphia, Pennsylvania | Psychological Stress of the Laboratory Experiment |
| 21 June 1977 | Loring B. Rowell, Ph.D.<br>Professor, School of Medicine<br>Department of Physiology & Biophysics<br>University of Washington<br>Seattle, Washington | Reflex Control of Skin Blood Flow - A Second Look |
| 1 July 1977 | Bjarne W. Olesen, Ph.D.<br>Laboratory of Heating & Air Conditioning<br>Technical University of Denmark<br>Denmark | The Influence of Asymmetric Thermal Environment on Man-Results from Recent Investigations at the Laboratory of Heating and Air Conditioning, Technical University of Denmark |

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| 22 August 1977 | Albert J. Tahmoush, MC<br>Neurologist, Department of Neuropsychiatry<br>Walter Reed Army Institute of Research<br>Washington, DC | Optical Estimation of Blood Flow and Blood Content; and Characteristics of an Optical System for the Relative Measurement of Blood Flow and Content |
| 7 July 1977 | Andrew J. Young, Ph.D.<br>Department of Biochemistry<br>North Carolina State University<br>Raleigh, North Carolina | Facilitated Diffusion of Oxygen in Tissue |
| 12 September 1977 | Jan Karlsson, M.D.<br>Physiology Institute GIH<br>Lidingovagen I<br>Stockholm, Sweden | Anaerobic Metabolism and the Expression of Muscle Strength |
| 19 September 1977 | Anthony J. Sargent, Ph.D.<br>MRC Environmental Physiology Unit<br>London School of Hygiene & Tropical Medicine<br>University of London<br>England | Muscle Function Following Disease Atrophy |

## SEMINAR PROGRAM

## PROFESSIONAL STAFF PRESENTATIONS

| DATE | LECTURER | SUBJECT |
|---|---|---|
| 22 October 1976 | Military Ergonomics Division | |
| | Ralph F. Goldman, Ph.D. | Prediction |
| | Kent B. Pandolf, Ph.D. | Heat and Work Studies |
| | Richard L. Burse, Sc.D. | Metabolic and Cold Studies |
| | John R. Breckenridge | Clothing Biophysics |
| 11 November 1976 | Exercise Physiology Division | |
| | James A. Vogel, Ph.D. | Program Objectives<br>Fort Jackson: An Evaluation of Physical Fitness in Men and Women Before and After Basic Training |
| | Donald H. Horstman, Ph.D. | Determination of Anaerobic Threshold |

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| | Donald H. Horstman, Ph.D. & CPT Dennis M. Kowal, MSC | Wellesley College: The Effects of Activity Experience and Training on the Perception of Effort by Women |
| | CPT Dennis M. Kowal, MSC | AFES: Efficacy of Performance Capacity Tests for Armed Forces Examination Stations |
| | | West Point: A Comparison of Effects of Two Types of Physical Training Programs on the Performance of 16-18 Year Old Women |
| 28 January 1977 | <u>Heat Research Division</u> | |
| | Milton Mager, Ph.D. | Malignant Hyperthermia |
| | Bernard J. Fine, Ph.D. | Heat Exposure: Effects on Complex Cognitive Tasks |
| | Ralph P. Francesconi, Ph.D. | Heat Acclimatization: Biochemical Responses |
| | MAJ Gaither D. Bynum, MC | Heatstroke Studies: Dog Model |
| | Roger W. Hubbard, Ph.D. | Heatstroke Studies: Rat Model |
| 2 February 1977 | <u>Experimental Pathology Division</u> | |
| | Murray P. Hamlet, D.V.M. | Film Presentation: Pulmonary Microcirculation |
| 28 February 1977 | <u>Altitude Research Division</u> | |
| | John T. Maher, Ph.D. | Introduction to Altitude Research Program and Pathophysiology of Acute Mountain Sickness |
| | Ronald A. Gabel, M.D. & Vladimir Fencl, M.D. | Ventilatory Adaptation to High Altitude |
| | John L. Kobrick, Ph.D. | Effects of Altitude on Psychological Processes Related to Military Performance |
| | MAJ Jimmie T. Sylvester, MC | Pulmonary Vascular Response to Hypoxia |
| | Allen Cymerman, Ph.D. | Thoracic Fluid Shifts During Military Operations at High Terrestrial Elevations |

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| 29 April 1977 | Experimental Pathology Division | | |
| | CPT Danney L. Wolfe, VC | Development of the Goat as a Model for Altitude Illness |
| | Wilbert D. Bowers, Ph.D. | Perfused Rat Liver as a Model of Heat Induced Illness |
| | CPT Joel J. Berberich, MSC | The Effects of Dehydration & Exercise on Hand Cooling |
| | CPT Lynn R. Trusal, MSC | Development of the Endothelial Cell Model System for the Study of Cold Injury |
| | CPT David R. Franz, VC | Effects of Fasiotomy & Vasodilators on Blood Flow of a Frostbite Model |
| 7 September 1977 | Heat Research Division | |
| | Milton Mager, Ph.D. & Roger W. Hubbard, Ph.D. | Exercise Brave Shield XVI |

# APPENDIX H

## AGENDA

## CURRENT CONCEPTS IN ENVIRONMENTAL (CLIMATIC) MEDICINE COURSE

16-20 May 1977

US ARMY RESEARCH INSTITUTE OF ENVIRONMENTAL MEDICINE

NATICK MASSACHUSETTS 01760

### PHYSICAL FITNESS AND WORK

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| Physiological Determinants of Work Performance, Work Capacity Evaluation and Training | Donald H. Horstman, Ph.D. |
| Physical Fitness Requirements in the Army | John F. Patton, Ph.D. |
| Psychological Determinants of Work Performance | LTC James W. Stokes, MC<br>Louis E. Banderet, Ph.D. |
| Sleeploss, Rapid Translocation Effects | LTC James W. Stokes, MC |
| Basic Training Requirements for Medical Units Committed to Cold Environments | MAJ James E. McCarroll, MSC |
| Physical Fitness as a Prerequisite to Working in Cold Environments | Donald E. Roberts, Ph.D. |
| Composition/Obesity | Richard L. Burse, Sc.D. |
| Summary: Operational Impact of Climatic Environments, Minimizing the Effects:<br>Cold<br>Heat<br>NBC<br>Altitude | Ralph F. Goldman, Ph.D. |

### COLD

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| Historical Aspects of Military Operations in Cold Environments | MAJ James E. McCarroll, MSC |

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| Major Problems of Military Units Operating in Cold Environments | MAJ James E. McCarroll, MSC |
| Cold Injury<br>Frostnip<br>Frostbite<br>Trenchfoot<br>Hypothermia | CPT James Jaeger, MSC |
| Pulmonary Effects of Cold Exposure (Fact or Fiction) | CPT James Jaeger, MSC |
| The Problem of Dehydration In Cold Environments | Donald E. Roberts, Ph.D. |
| Film: Prevention of Cold Injury | Donald E. Roberts, Ph.D. |
| Exercise and Work in Cold Environments | Donald E. Roberts, Ph.D. |
| Combat and Environmental Stress as Compounding Factors During Cold Weather Operations | James B. Sampson. Ph D |
| Protection Against Cold - Assessment of Clothing | Ralph F. Goldman, Ph.D. |
| Prediction Modelling of Hypothermia (water immersion heat loss) and Extremity Cooling | Ralph F. Goldman, Ph.D. |

<u>HEAT</u>

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| Introduction: (1) Historical<br>(2) Responses of Man to Heat | Milton Mager, Ph.D |
| Temperature Regulation and Heat Acclimatization | Ralph Francesconi, Ph.D. |
| Film: "Prevention of Heat Injury" | |
| Heat Illness: Prevention, Diagnosis & Treatment | Roger W. Hubbard, Ph.D. |
| Computer Prediction of Heat Stress: Effects of Environment, Clothing, Load and Acclimatization | Leander A. Stroschein, BA |

## HIGH TERRESTRIAL ELEVATIONS

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| Adaptive Responses to High Altitude | MAJ Jimmie T. Sylvester, MC |
| Clinical Problems of Altitude Exposure | John T. Maher, Ph.D. |

## DEMONSTRATIONS

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| Assessment of the Thermal Environment | Ralph F. Goldman, Ph.D. |
| Demonstration of Environmental and Physiological Measuring Equipment and Facilities | John R. Breckenridge, BS<br>Fred R. Winsmann, MS |
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